federal register

FRIDAY, DECEMBER 19, 1975

PART IV:

NATIONAL COMMUNICATIONS SYSTEM

■

TELECOMMUNICATIONS; BIT ORIENTED DATA LINK CONTROL PROCEDURES

Proposed Federal Standard

NATIONAL COMMUNICATIONS SYSTEM

TELECOMMUNICATIONS: BIT ORIENTED DATA LINK CONTROL PROCEDURES

Proposed Federal Standard 1003

NOTE: This document, FR Doc. 75-33358, was originally published at 40 FR 57721 (Thursday, December 11, 1975). At that time, the text of the proposed Standard 1003 was inadvertently filed as part of the original document. Today's republication contains the text of the standard.

The Administrator of the General Services Administration (GSA) is responsible, under the provisions of the Federal Property and Administrative Services Act of 1949, as amended, for the Federal Standardization Program. On 14 August 1972, the National Communications System (NCS) [1] was designated by the Administrator, GSA, as the responsible agent for the development of telecommunication standards for NCS interoperability and the computer-communications interface. The Federal Telecommunication Standards Committee (FTSC) was established under the administration of NCS to accomplish this mission. Additionally, the Secretary of Commerce is authorized, under the provisions of Public Law 89-306, to develop and establish uniform Federal automatic data processing standards.

This proposed Federal standard is part of a series of joint Federal telecommunication standards and Federal Information Processing Standards (FIPS) falling within the area of mutual responsibility of the NCS and the National Bureau of Standards (NBS) as defined in FIPS PUB 23 [2] and NCS Circular 175-1 [3].

The proposed Federal standard and the companion FIPS publication will adopt the content of the American National Standards Institute (ANSI) document X3S34/589, 15 August 1975, with the exceptions set forth in paragraph 2, "Applicable Documents." The ANSI document specifies the data communication control procedures, which define the means for exchanging data between business machines (e.g., computers, concentrators and terminals) over communication circuits. The advanced data communication control procedures described are synchronous, bit oriented (i.e., use bit patterns instead of ASCII characters for control), code independent (i.e., capable of handling any data code or pattern) and interactive (i.e., have relatively high efficiency in an interactive application). The proposed ANSI document was developed by an ANSI task group with Federal Government participation and has been recommended for processing as a Federal standard by the FTSC with the concurrence of the National Bureau of Standards in response to requirements specified by various Government agencies.

Prior to submission of the final endorsement of the proposed Federal standard and its companion FIPS publication to the Department of Commerce (DOC), the Office of Telecommunications Policy (OTP), Executive Office of the President, and GSA, it is essential that proper consideration is given to the needs and views of industry, the public, and state and local governments. The purpose of this notice is to solicit such views. Interested parties may submit their comments to the Office of the Manager, National Communications System, ATTN: NCS-TS, Washington, D.C. 20305. All comments should be submitted to NCS by 30 January 1976.

LEE M. PASCHALL,
Lieutenant General, USAF,
Manager.

MAURICE W. ROCHE,
Director, Correspondence and
Directives, OASD (Comptroller).

DECEMBER 8, 1975.

PROPOSED FEDERAL STANDARD

TELECOMMUNICATIONS: BIT ORIENTED DATA LINK CONTROL PROCEDURES

This standard is issued by the General Services Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended. Its application to both data processing systems and telecommunications systems is mandatory on all Federal agencies to the extent specified herein. Do not use prior to approval.

FOREWORD

The Telecommunication series of Federal Standards are designed to facilitate interoperability between telecommunication facilities and systems of the Federal Government and compatibility of these facilities and systems at the computer-communications interface with data processing equipment (systems).

[1] DoD Directive 5100.41, "Arrangements for Discharge of Executive Agent Responsibilities for the NCS"—filed as part of original document.

[2] Filed as part of original. Copies available from U.S. Government Printing Office, Washington, D.C. 20402 (order by SD Catalog No. C13.52:23)

[3] Filed as part of original. Copies available from Office of the Manager, NCS, Washington, D.C. 20305

FED-STD-1003
January, 1976

PROPOSED
FEDERAL STANDARD

TELECOMMUNICATIONS: BIT ORIENTED DATA LINK CONTROL PROCEDURES

1. Scope. This standard specifies the frame structure, elements of procedures, and codes of practice (classes of procedure) for data communications systems that transmit synchronous binary data, including binary coded data, by electrical or electromagnetic means and which have automatic error detection capabilities.

1.1 Application. This standard shall be used by all Federal agencies in the design and procurement of equipment and systems. It applies to equipment and systems that are procured after the effective date of this standard. Those new systems and equipments on which substantial technical design has been completed before the effective date of which are procured as replacements in or extensions to existing systems may file for exception.

2. Applicable Documents. This Federal standard embodies the content of the American National Standards Institute document X3S34/589, "Proposed American National Standard for Advanced Data Communication Control Procedures (ADCCP) (Independent Numbering)," dated 15 August 1975, except for the aspects listed below:

a. All systems conforming to this Federal standard shall be able to implement the 16-bit frame check sequence (FCS) described in paragraph 3.5, section 12, and appendix D. In addition, if a 32-bit FCS is required for some applications, it shall use the generating polynomial

$$x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^{8}+x^{7}+x^{5}+x^{4}+x^{2}+x^{1}+1$$

b. The user defined commands and responses, USER0, USER1, USER2, and USER3, appearing in the introduction to section 7, paragraph 7.4, the introduction to paragraph 7.5, and paragraph 7.5.4.2 are not a part of the Federal standard.

3. Changes. When a Federal agency considers that this standard does not provide for its essential needs, a statement citing inadequacies shall be sent in duplicate to the General Services Administration, Federal Supply Service, FMH, Washington, DC, 20406 (in accordance with provisions of Federal Property Management Regulations 4, CFR SS 101-29.3). The General Services Administration will determine the appropriate action to be taken and will notify the agency.

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LIST OF ABBREVIATIONS

A - Secondary station address field
ADCCP - Advanced Data Communication Control Procedures
ADM - Asynchronous Disconnect Mode
ARM - Asynchronous Response Mode
ARME - Asynchronous Response Mode Extended
BCB - Balanced Control Basic Recovery
BCS - Balanced Control SREJ Recovery
C - Control Field
CCITT - International Telegraph and Telephone Consultative Committee
CMDR - Command Reject (Response)
DISC - Disconnect (Command)
DM - Disconnect Mode (Response)
ECMA - European Computer Manufacturers Association
ERP - Exception (or Error) Recovery Procedure
F - Flag
F bit - Final Bit
FCS - Frame Check Sequence
I - Information Format (frame)
I frame - Information Format frame
IM - Initialization Mode
Info - Information Field
ISO - International Standards Organization
LSB - Least Significant Bit
M - Modifier Bit
MP - Multipoint
MSB - Most Significant Bit
N - A Number variable
NA - Not Applicable
NAB - Normal and Asynchronous Response Mode, Basic Recovery
NAS - Normal and Asyncrhronous Response Mode, SREJ Recovery
NB - Normal Response Mode, Basic Recovery
NDM - Normal Disconnect Mode
N(R) - Receive Sequence Number
NRM - Normal Response Mode
NRME - Normal Response Mode Extended
N(S) - Send Sequence Number
NS - Normal Response Mode, SREJ Recovery
P bit - Poll Bit
P/F bit - Poll or Final Bit
Pri - Primary
P-P - Point-to-point
P-S - Primary-to-Secondary
P/S - Primary or Secondary
Pri/Sec - Primary or Secondary

R - Receive State Variable
RD - Request Disconnect (Command)
REJ - Reject (Command, Response)
RIM - Request Initialization Mode (Response)
RNR - Receive Not Ready (Command; Response)
RR - Receive Ready (Command, Response)
RSPR - Response Reject (Command)
S - Depending upon usage : - Send State Variable
- Supervisory Bit
- Supervisory Format (frame)
S frame - Supervisory Format frame
SARM - Set Asynchronous Response Mode (Command)
SARME - Set Asynchronous Response Mode Extended (Command)
Sec - Secondary
SIM - Set Initialization Mode (Command)
SNRM - Set Normal Response Mode (Command)
SNRME - Set Normal Response Mode Extended (Command)
SREJ - Selective Reject (Command, Response)
TO - Timeout
TWA - Two-Way Alternate
TWS - Two-Way Simultaneous
U - Unnumbered Format (frame)
U frame - Unnumbered Format frame
UA - Unnumbered Acknowledge (Response)
UI - Unnumbered Information (Command, Response)
UP - Unnumbered Poll (Command)
USER - User (Command, Response)
XID - Exchange Identification (Command, Response)
w, x, y, z - bits in CMDR Status Field

NOTE: The mathematical symbols and abbreviations used in Section 12.0, Frame Check Sequence (FCS) Generation and Checking, and Appendix D, Frame Check Sequence (FCS), are not included above; they are defined as they introduced in Section 12 and Appendix D.

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1.0 SCOPE

This standard is intended to cover a wide range of applications (e.g., two-way alternate and two-way simultaneous data communication between conputers, concentrators and terminals which are normally buffered) and a wide range of data link configurations (e.g., full and half duplex, multi-point, point-to-point, switched or non-switched).

This standard establishes the procedures to be used on synchronous communication links using ADCCP - Independent Numbering. This standard does not define any single system and should not be regarded as a specification for a data communications system.

These procedures are defined specifically in terms of the actions that occur on receipt of commands at a Secondary.

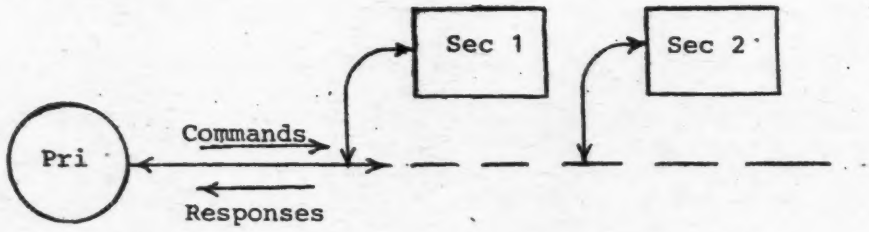
In order to provide a high degree of standardization (and, therefore, of compatibility), any equipment intended to be operated within the constraints of this standard shall implement all features of a stipulated class of the procedures.

2.0 DATA LINK CONFIGURATIONS

ADCCP-Independent Numbering defines a Primary/Secondary link which has a primary link control function (referred to as Primary), and a secondary link control function (referred to as secondary). The primary is responsible for initialization, scheduling of data flow, and initiation of link level error recovery functions. Each secondary is responsible for executing commands received from the primary, and for responding when instructed by the primary.

2.1 Primary/Secondary Link

The Primary/Secondary link configuration includes one primary station and one or more secondary stations, as shown in Figure 1. The link may be point-to-point or multipoint, half duplex or full duplex, switched or non-switched. In this configuration all data transfer and link error recovery functions are controlled by the single primary station.



Point-to-Point or multipoint, half duplex or full duplex, switched or non-switched link

FIGURE 2-1 - PRIMARY/SECONDARY LINK

3.0 FRAME STRUCTURE

In ADCCP - Independent Numbering, all transmissions are in frames and each frame conforms to the following structure:

F, A, C, Info, FCS, F

Where:

F = Flag Sequence

A = Secondary Station Link Address Field

C = Control Field

Info = Information Field

FCS = Frame Check Sequence

Frames containing only data link control sequences form a special case where there is no Info field. The short frame structure is therefore:

F, A, C, FCS, F

The elements of the frame are described in the following paragraphs. See also Figure 3-1.

3.1 Flag Sequence (F)

All frames start and end with the flag sequence. This sequence is a zero bit followed by 6 one bits followed by a zero bit (01111110). All stations attached to the data link continuously hunt, on a bit-by-bit basis, for this sequence. However, a transmitter must send only complete eight-bit flags. Thus, the flag is used for frame synchronization.

In order to achieve transparency the flag sequence is prohibited from occurring in the Address, Control, Information and FCS Fields via a "zero bit insertion" procedure which is described in paragraph 3.7.

Where station constraints permit, the flag sequence which closes a frame may also be the opening flag sequence for the next frame. Any number of complete flags may be used between frames. (See also Appendix B)

3.2 Secondary Station Link Address Field (A)

The Secondary Station Link Address Field follows the opening flag of every frame from both primary and secondary stations. The length of this field (A) is N octets (N greater than or equal to 1). The encoding of this field is described in Section 4.

3.3 Control Field (C)

The Control Field contains commands, responses, and sequence numbers. The control field is used by the primary to instruct the addressed secondary what operation it is to perform. It is also used by the secondary to respond to the primary. The length of this field (C) is normally one octet. It is two octets in length in the case of the extended control field (see Section 5.2.2).

Sequence numbers and the formatting of the Control Field are described in Section 5. Commands and responses are functionally described in Section 7.

3.4 Information Field (Info)

The Information field may be any number and sequence of bits; the data link is completely transparent. Data contained in the information field is unrestricted with respect to code or grouping of bits. See Appendix B for examples of typical limitations on maximum length. An information field length of zero is specifically permitted.

3.5 Frame Check Sequence (FCS)

All frames include a 16-bit frame check sequence (FCS) just prior to the closing flag for error detection purposes. The contents of the Address, Control and Information fields, excluding the zeros inserted to maintain transparency per Section 3.7, are included in the calculation of the FCS sequence.

The FCS is the remainder of a modulo 2 division process utilizing a generator polynomial as a divisor. The generator polynomial is that used in CCITT Recommendation V.41 and is: $X^{16} + X^{12} + X^5 + 1$.

Section 12 gives a complete description of the FCS generation process and the error checking process which utilizes the FCS. Appendix D gives an example of FCS generation and error detection.

NOTE: If future applications show that a higher degree of protection is needed, the length of the FCS sequence shall be increased by multiples of eight bits. This requires a higher degree generator polynomial the implementation of which is outside of this standard.

3.6 Abort

Abort is the procedure by which a station in the process of sending a frame, ends the frame in an unusual manner such that the receiving station will ignore the frame.

Aborting a frame is performed by transmitting at least seven, but less than fifteen, contiguous one bits (with no inserted zeros). Receipt of seven contiguous one bits is interpreted as an abort. Receipt of fifteen or more contiguous one bits is interpreted as an abort and Idle Link State (see Section 3.9).

3.7 Transparency

ADCCP provides transparency for data coded in the Information field. The occurrence of the flag sequence within a frame is prevented via a "zero bit insertion" procedure as follows:

The transmitter inserts a zero bit following five contiguous one bits anywhere between the beginning flag and the ending flag of the frame. The insertion of the zero bit thus applies to the contents of the Address, Control, Info and FCS fields (including the last 5 bits of the FCS). The receiver continuously monitors the received bit stream; upon receiving a zero bit followed by five contiguous one bits, the receiver inspects the following bit: If a zero, the 5 one bits are passed as data and the zero bit deleted. If the sixth bit is a one, the receiver inspects the seventh bit; if it is zero, a flag sequence has been received; if it is a one an abort has been received (See Section 3.6).

3.8 Active Link State

A link is in an ACTIVE state when the Primary or a Secondary is actively transmitting a frame, an abort sequence, or interframe time fill. When the link is in the active state the right of the transmitting station to continue transmission is reserved.

3.8.1 Interframe Time Fill

Interframe time fill is accomplished by transmitting continuous flags between frames. There is no provision for intraframe time fill. (See also Appendix B.)

3.9 Idle Link State

A link is defined to be in an IDLE state when a continuous ones state is detected that persists for 15 bit times.

Idle link time fill is defined to be a continuous one condition on the link.

3.10 Invalid Frame

An invalid frame is defined as one that is not properly bounded by two flags (thus an aborted frame is an invalid frame) or one which is too short (that is, shorter than 32 bits between flags). A Secondary will ignore any invalid frame.

3.11 Order of Bit Transmission

Addresses, commands and responses, and sequence numbers are to be transmitted low order bit first (e.g., the first bit of sequence number that is transmitted carries the weight 2^0).

The order of bit transmission for data contained within the information field is application-dependent and not specified.

The order of bit transmission for the FCS is most significant bit first (See Appendix D).

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FRAME

First Bit Transmitted

F	A	C	(Info)	FCS	F
01111110	Note 1	Note 2	Note 3	X^{15}----------X^{0}	01111110
Flag Sequence	Address Field	Control Field	Information Field	Frame Check Sequence	Flag Sequence

Note 1. Address Field formats described in Sections 4.2 & 4.3

Note 2. Control Field formats described in Sections 5.2.1 & 5.2.2

Note 3. Information Field may be any number of bits ≥0.

STRUCTURAL RELATIONSHIP OF DEFINED FIELDS IN ADCCP FORMAT

Figure 3.1

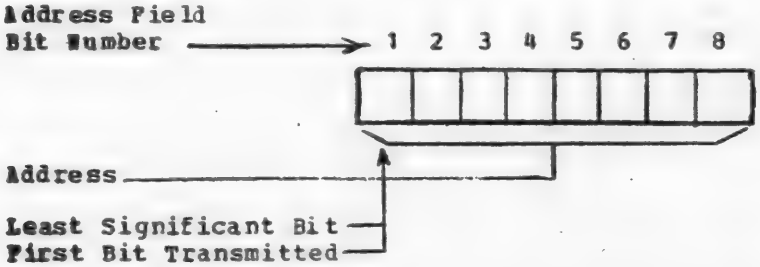
4.0 SECONDARY LINK ADDRESS FIELD

4.1 Addressing Modes

Two addressing modes are defined for the secondary station link address field. These modes are mutually exclusive for any given Secondary on a link and therefore the addressing mode must be explicitly specified.

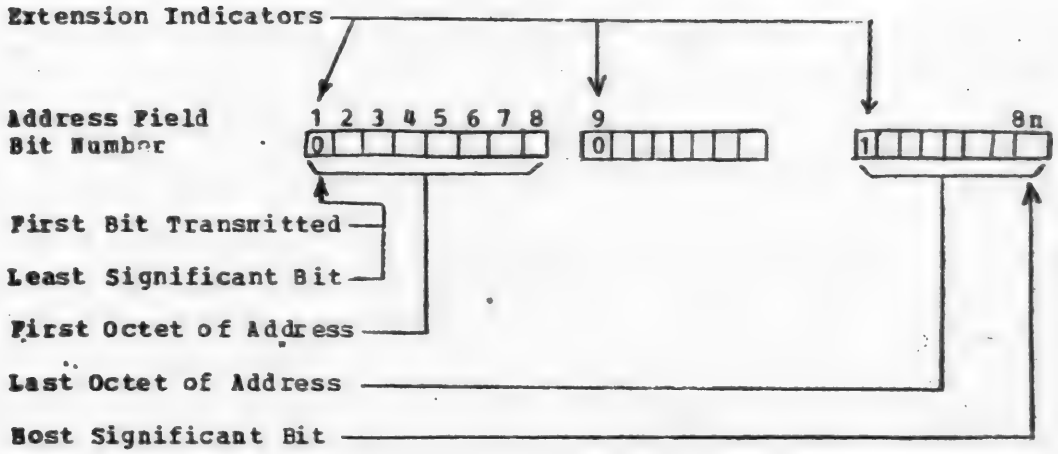
4.2 Secondary Link Address Field - Basic Address Mode

In basic mode, the secondary link address field contains one address, which may be a single, group, or global secondary address. This field consists of one octet with the following format:



4.3 Secondary Link Address Field - Extended Address Mode

In extended mode, the secondary link address field is a sequence of octets which comprises one address which may be a single, group, or global Secondary address. When the first bit of an address octet is "0", the following octet is an extension of the address field. The address field is terminated by an octet having a "1" in bit position one. Thus, the address field is recursively extendable. The format of the extended secondary link address field is:



4.4 Global Address

The address of eight "1" bits (11111111) is reserved as the global (universal, or broadcast) address.

The global address is used in situations where a specific Secondary address is not known (e.g., switched connection), or is not necessary to the situation (e.g., broadcast transmission).

4.5 Null Address

The address of eight "0" bits (00000000) is reserved as the null (no-station) address.

The null address is used in situations where it desired to exercise a station transmit ability without requiring remote station action or reply.

5.0 TRANSMISSION PARAMETERS AND FORMATS

5.1 Parameters

The various parameters associated with the transmission formats are described in the following sections.

5.1.1 Modulus

Each Information (I) frame is sequentially numbered and may have the value 0 through modulus minus 1 (where modulus is the modulus of the sequence numbers). Modulus equals 8 for the basic control field and 128 for the extended control field. The sequence numbers cycle through the entire range.

The maximum number of sequentially numbered I frames that the Primary or Secondary may have outstanding (i.e., unacknowledged) at any given time may never exceed one less than the MODULUS of the sequence numbers. This restriction is to prevent any ambiguity in the association of transmitted I frames with sequence numbers during normal operation and/or error recovery action. The number of outstanding I frames may be further restricted by either the sending or receiving station storage capability; e.g., the number of I frames that can be stored for transmission and/or retransmission in the event of a transmission error.

5.1.2 Frame Variables and Sequence Numbers

In ADCCP-Independent Numbering operation each addressed Secondary station maintains a separate (independent) Send Sequence Number, N(S), and a Receive Sequence Number, N(R), on the I frames it sends and receives. Each Secondary station then maintains an N(S) number on the frames it transmits to the Primary, and an N(R) number on the I frames it has correctly received from the Primary. In the same manner the Primary maintains separate N(S) and N(R) numbers for I frames sent to and received from each Secondary on the link.

5.1.3 Send State Variable, S

A Primary station and all Secondary stations capable of transmitting I frames have a state variable, S, which denotes the sequence number of the next in sequence I frame to be transmitted. S can take on the value 0 through MODULUS -1. (Where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of S is incremented by one with each successive I frame transmission, but cannot exceed N(R) of the last received frame by more than MODULUS -1.

5.1.4 Send Sequence Number, N(S)

Only I frames contain N(S), the sequence number of transmitted frame. Prior to transmission of an in sequence I frame, the value of N(S) is updated to equal the value of S.

5.1.5 Receive State Variable, R

A Primary station and all Secondary stations capable of receiving I frames have a state variable, R, which denotes the sequence number of the next in sequence I frame to be received. R can take on the values 0 through MODULUS -1 (where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of R is incremented by the receipt of an error free in sequence I frame whose send sequence number, N(S), equals R.

5.1.6 Receive Sequence Number, N(R)

All I frames and S frames contain N(R), the expected sequence number of the next received I frame. Prior to transmission or retransmission of a frame of the above types, the value of N(R) is updated to equal the current value of R. N(R) indicates that the station transmitting the N(R) has correctly received all I frames numbered up to and including N(R)-1.

5.1.7 Poll/Final, P/F, Bit

The Poll (P) bit is used by the Primary to solicit (poll) a response or sequence of responses from Secondary stations.

The Final (F) bit is used by a Secondary to:

1) indicate in ARM the response frame sent in reply to the receipt of a poll command.

2) in NRM to indicate the final frame transmitted as the result of a previous poll command.

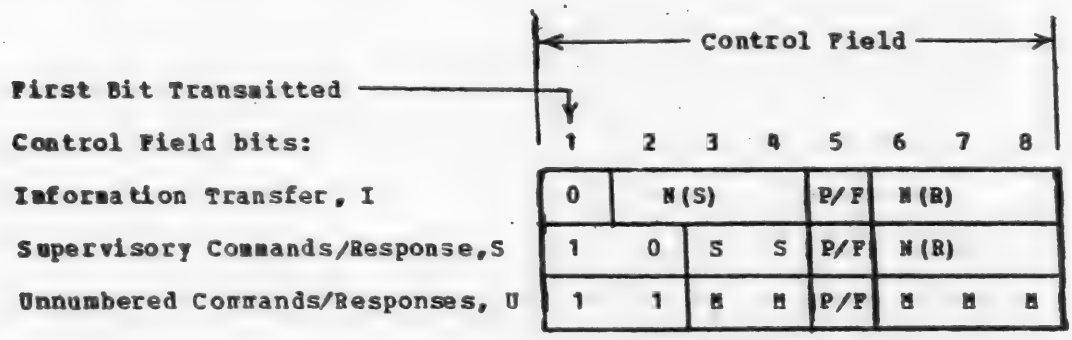
See Section 6.1 for further description of the P/F bit operation.

5.2 Control Field Formats

The three formats defined for the Control field are used to perform information transfer, basic supervisory control functions, and special or infrequent control functions.

5.2.1 Basic Control Field

The basic control field accomodates molulo 8 N(S) and N(R) sequence numbering.


Control Field
First Bit Transmitted
Control Field bits:
1 2 3 4 5 6 7 8
Information Transfer, I
0 N(S) P/F N(R)
Supervisory Commands/Response, S
1 0 S S P/F N(R)
Unnumbered Commands/Responses, U
1 1 M M P/F M M M

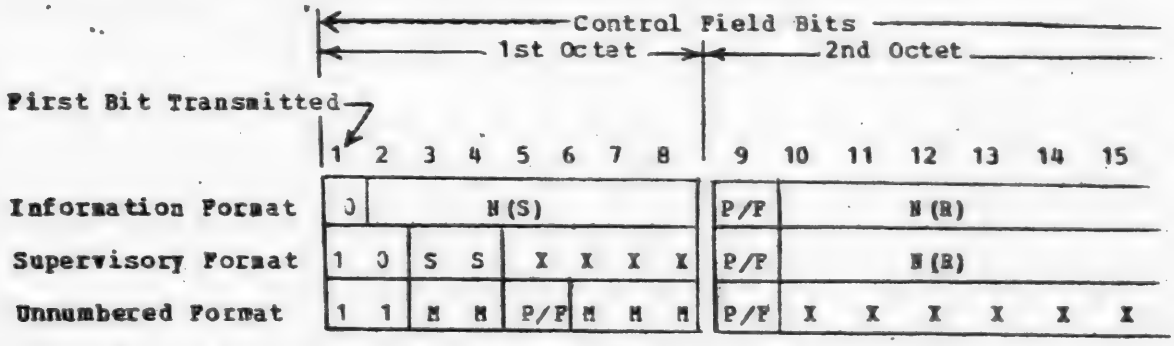
Where: N(S) = Transmitting station send sequence number.
(Bit 2 = Low Order Bit)
N(R) = Transmitting station receive sequence number.
(Bit 6 = Low Order Bit)
S = Supervisory function bits
M = Modifier function bits
P/F = Poll bit - Primary transmissions.
Final bit - Secondary transmissions.

(1 = Poll/Final)

5.2.2 Extended Control Field

The extended control field accommodates modulo 128 N(S) and N(R) sequence numbering. (On long propogation delay links (e.g., satellite transmission) it is desirable for reasons of efficiency to extend the modulus of the sequence numbers N(S) and N(R). The method of extension is defined below.)

Control field extension for the three formats is as follows:


Control Field Bits
1st Octet
2nd Octet
First Bit Transmitted
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Information Format
0 N(S) P/F N(R)
Supervisory Format
1 0 S S X X X X P/F N(R)
Unnumbered Format
1 1 M M P/F M M M P/F X X X X X X

where X bits are reserved and set to "0"

5.3 Information Transfer Format - I

The I format is used by Primary and Secondary stations to perform an information transfer.

The functions of N(S), N(R), and P/F are independent; i.e., each I frame has an N(S) sequence number, the N(R) sequence number may or may not acknowledge additional I frames at the receiving station, and the P/F bit may or may not be set to "1".

5.4 Supervisory Format - S

The S format is used to perform link supervisory control functions such as acknowledge I frames, request retransmission of I frames, and indicate temporary interruption of capability to receive I/UI frames.

5.5 Unnumbered Format - U

The U format is used to provide additional Primary and Secondary link control functions. This format contains no sequence numbers and consequently 5 "modifier" bit positions are available which allows definition of up to 32 additional command and 32 additional response functions.

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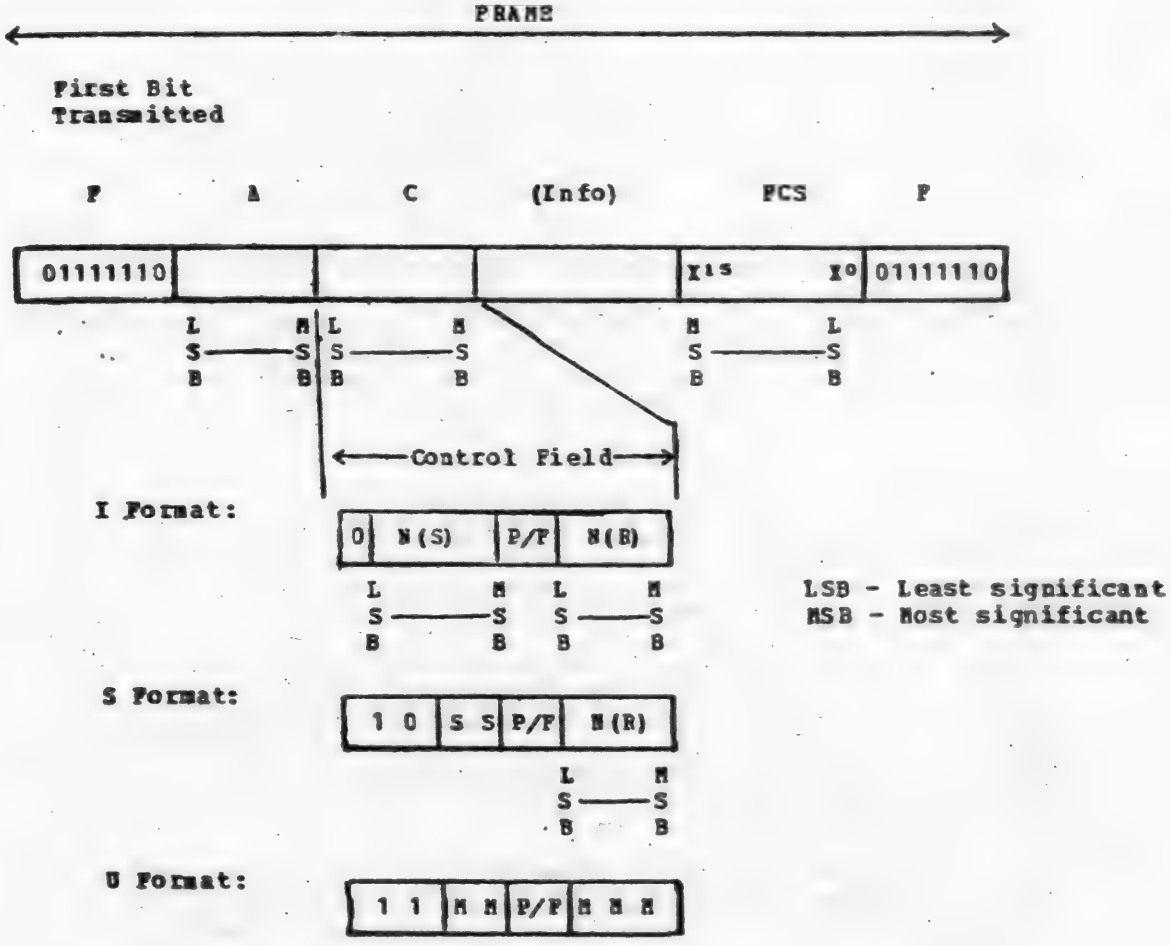

POSITIONAL SIGNIFICANCE OF BITS IN FIELDS OF ADCCP BASIC FORMAT

Figure 5-1

6.0 SECONDARY MODES

6.1 Operational Modes

There are two link level operational modes: Normal Response Mode (NRM) and Asynchronous Response Mode (ARM). A Secondary in either of these modes is fully operational and capable of transmitting and receiving I, S, and U format frames.

Secondary stations do not queue sequential responses for command frames received. A Secondary station response is predicated on: 1) station status at that time the response is transmitted; 2) an exception condition previously established, or; 3) the previous receipt of a command which requires a specific response format.

6.1.1 Normal Response Mode, NRM

NRM is a Secondary station operational mode in which the Secondary station may initiate transmission only as the result of receiving a command frame with the Poll (P) bit set to "1". Upon receiving a command frame with the P bit set to "1" the Secondary station shall initiate a response transmission. The response transmission may consist of one or more frames while maintaining an Active Link State. In all cases the last frame of the response transmission will have the Final (F) bit set to "1". When the response frame with the F bit set to "1" is transmitted the Secondary station will stop transmitting and not initiate any additional transmission until a subsequent command frame is received with the P bit set to "1".

The N(R) number of a received frame which has the Poll (command) or Final (response) bit set to "1" will cause the receiving station to initiate appropriate recovery procedures if all I frames transmitted previous to and/or concurrent with the last frame which was transmitted with the Poll (Primary) or Final (Secondary) bit set to "1" have not been acknowledged. In all cases the receipt of an I or S format frame will confirm previously transmitted I frames through N(R)-1.

Normal Response Mode Extended, NRME, is operationally identical to NRM except that for the extended control field. See Section 5.2.2.

6.1.2 Asynchronous Response Mode, ARM

ARM is a Secondary station operational mode in which the Secondary station may initiate transmission without regard to the receipt of a command frame with the Poll bit set to "1". Asynchronous transmission may be initiated at the first respond opportunity, which for two-way alternate (TWA) transmission is detection of an Idle Link State, and for two-way simultaneous (TWS) transmission is immediately. An asynchronous transmission may contain multiple frames and is used to initiate information transfer (I/UI) and/or to report status changes in the Secondary Station, (e.g., N(R) number change, transition from a ready to a busy condition or vise versa, establishment of an exception condition.)

The Secondary station will transmit a frame with the Final bit set to "1" only in response to a received command frame with the Poll bit set to "1". Following the receipt of a command frame with the Poll bit set to "1" the Secondary station must initiate a response transmission with the Final bit set to "1". Additional response frames may be transmitted following the response frame which had the Final bit set to "1".

In the case of a TWS Secondary station which is in the process of transmitting when the command with the Poll bit set to "1" is received, the Final bit will be set to "1" in the earliest possible subsequent frame to be transmitted.

The N(R) number of a received frame which has the Poll (command) or Final (response) bit set to "1" will cause the receiving station to initiate appropriate recovery procedures if all I frames transmitted previous to and/or concurrent with the last frame which was transmitted with the Poll (Primary) or Final (Secondary) bit set to "1" have not been acknowledged.

In ARM a Secondary station has a response timer which will cause initiation of appropriate recovery procedures if previously transmitted frames have not been acknowledged by the Primary station within a system specified timeout period. Since simultaneous contention may occur in the case of TWA configurations, the interval employed by the Secondary station must be greater than that employed by the Primary station so as to permit contention situations to be resolved in favor of the Primary station.

Asynchronous Response Mode Extended, ARME, is operationally identical to ARM except for the extended control field. See Section 5.2.2.

6.2 Disconnected Modes

There are two link level disconnected modes: Normal Disconnected Mode (NDM) and Asynchronous Disconnected Mode (ADM). These disconnected modes are provided to prevent a Secondary from appearing on the link in a fully operational mode during unusual situations or exception conditions since such operation could cause 1) unintended contention in ARM, 2) sequence number mismatch between the Primary and Secondary, or 3) ambiguity in the Primary as to the Secondary status or mode.

In NDM or ADM the Secondary is logically disconnected from the data link; i.e., no information field (I/UI) or S frames are transmitted or accepted. The Secondary capability in either NDM or ADM is limited to 1) accepting one of the mode-setting commands, 2) transmitting a DM or RIM response frame at each respond opportunity, and 3) responding to an XID command.

A Secondary is system defined as to the condition(s) that cause it to assume one of the two predetermined modes (ADM or NDM).

Examples of possible conditions (in addition to receiving a DISC command) which may cause a Secondary to change to a disconnected mode are:

1. the Secondary power is turned on

2. the Secondary has a temporary loss of power

3. the Secondary link level logic is manually reset

4. the Secondary terminal is manually switched from a local (home) condition to a connected-to-the-link (on-line) condition.

A Secondary in NDM or ADM may not establish a Command Reject exception condition.

6.2.1 Normal Disconnected Mode, NDM

NDM is a Secondary disconnected mode in which the Secondary is logically disconnected from the data link (i.e., not in an operational status) and has normal mode respond opportunity protocol; i.e., it may initiate a response transmission (per Section 6.1.1) only as the result of receiving a command frame with the P bit set to "1".

In this mode a Secondary actions only mode setting and XID commands. Valid commands received with the P bit set to "1" cause a Secondary in NDM to respond with a Disconnect Mode (DM) response or, if the Secondary determines it is unable to continue functioning, a request for initialization (RIM). Valid commands received with the P bit set to "0" are ignored by the Secondary.

6.2.2 Asynchronous Disconnected Mode, ADM

ADM is a Secondary disconnected mode in which the Secondary is logically disconnected from the data link (i.e., not in an operational mode) and has asynchronous respond opportunity protocol; i.e., it may initiate a response transmission (per Section 6.1.2) in TWA exchange upon detection of an Idle Link State, and in TWS exchange at any time. Such a response transmission will only consist of a request for logical connection to the Primary (DM) or, a request for initialization (RIM) if the Secondary determines it is unable to continue functioning.

In this mode a Secondary actions only mode setting and XID commands.

6.3 Initialization Mode, IM

IM is a mode of operation in which the Secondary link control program is initialized or regenerated by Primary action. IM is invoked when a Primary concludes a Secondary is behaving abnormally and needs its link control program corrected, or to remotely upgrade the Secondary's link control program. In like manner a Secondary may determine it is unable to continue functioning due to program checks and request IM to obtain a good program from the Primary.

A Secondary enters the IM upon sending a UA response in reply to the receipt of a Set Initialization Mode (SIM)

command. The Secondary may request SIM by sending Request Initialization Mode (RIM). In IM, the Primary and Secondary may exchange information in any manner specified for that Secondary station (i.e., unformatted and unchecked bit streams, UI frames, or I frames). IM is ended when the Secondary receives, actions, and acknowledges (via a UA response) a mode setting command, i.e., SNRM, SARM, SNRME, SARME, or DISC.

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7.0 COMMANDS AND RESPONSES

This standard defines the link control operation of each secondary station control in terms of command frames, response frames and internal modes. The actual link management procedure (i.e., sequence of commands and related responses) is application and link configuration dependent. Consequently, specific Primary command sequences are not defined but left to the designer of the primary link control.

Sections 7.1 through 7.3 contain the definition of the set of commands and responses (listed below) for each of the transmission formats.

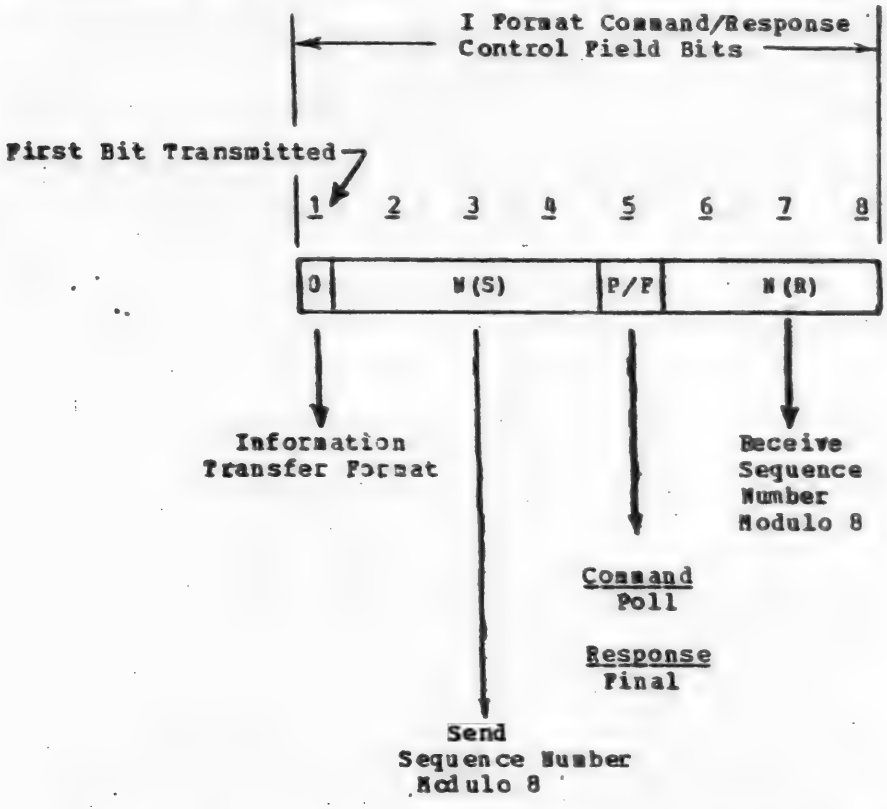
Information Transfer Format Commands	Information Transfer Format Respons
I - Information	I - Information
Supervisory Format Commands	**Supervisory Format Responses**
RR - Receive Ready	RR - Receive Ready
RNR - Receive Not Ready	RNR - Receive Not Ready
REJ - Reject	REJ - Reject
SREJ - Selective Reject	SREJ - Selective Reject

Unnumbered Format Commands	Unnumbered Format Responses
Mode Setting Commands	**Mode Setting Responses**
SNRM - Set Normal Response Mode	UA - Unnumbered Acknowledge
SARM - Set Asynchronous Response	DM - Disconnected Mode
SNRME - Set Normal Response Mode Extended	RIM - Request Initialization Mode
SARME - Set Asynchronous Response Mode Extended	RD - Request Disconnect
SIM - Set Initialization Mode	
DISC - Disconnect	
Information Transfer Commands	**Information Transfer Responses**
UI - Unnumbered Information	UI - Unnumbered Information
UP - Unnumbered Poll	
Recovery Commands	**Recovery Responses**
RSPR - Response Reject	CMDR - Command Reject
Miscellaneous Commands	**Miscellaneous Responses**
USER - User Defined (4 code positions)	USER - User Defined (4 code positions)
XID - Exchange Identification	XID - Exchange Identification

7.1 Information Transfer Format, I, Command and Response

The function of the Information, I, command and response is to efficiently transfer sequentially numbered frames containing an information field across a link.

The encoding of the I command/response control field is:



The I frame control field contains two sequence numbers: N(S), Send Sequence Number, which indicates the sequence number associated with the I frame; N(R), Receive Sequence Number which indicates the sequence number of the next expected I frame to be received (i.e., I frames numbered up to and including N(R)-1 have been correctly received).

An I frame with P bit set to "1" may be used to reset a busy condition that was initiated by the transmission of RNR. See Section 7.2.2.

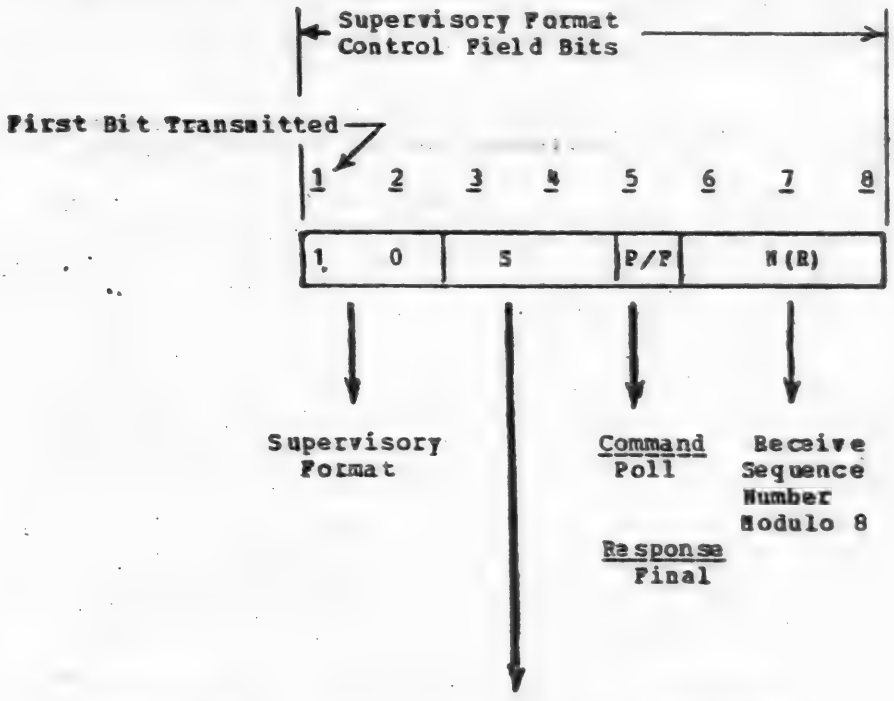
See Section 6.1 for description of P/F bit operation.

7.2 Supervisory Format, S, Commands and Responses

Supervisory, S, commands and responses are used to perform basic supervisory link control functions such as I frame acknowledgement, polling, temporary interruption of information (I/UI) transfer, and error recovery.

Frames with the S format do not contain an information field and therefore do not increment the Send Sequence Numbers N(S) at either the transmitting or receiving station.

The encoding of the S command/response control field is:



Commands		Responses
RR - Receive Ready	00	Receive Ready
RNR - Receive Not Ready	10	RNR - Receive Not Ready
REJ - Reject	01	REJ - Reject
SREJ - Selective Reject	11	SREJ- Selective Reject

A S frame contains an N(R), Receive Sequence Number, which indicates the sequence number of the next expected I frame to be received (i.e., all received I frames numbered up to and including N(R)-1 have been correctly received.) See Section 6.1 for description of the P/F bit operation.

7.2.1 Receive Ready, RR, Command and Response

The receive Ready, RR, is used by the Primary or Secondary to: 1) indicate it is ready to receive an I frame 2) acknowledge previously received I numbered up to and including N(R)-1.

The Primary may use the RR command with the Poll bit set to "1" to solicit responses from (poll) Secondary stations.

An RR frame may be used to reset a busy condition that was initiated by the transmission of RNR. See Section 7.2.2.

7.2.2 Receive Not Ready, RNR, Command and Response

The Receive Not Ready, RNR, is used by the Primary or Secondary to indicate a "busy" condition; i.e., the temporary inability to accept additional incoming information (I or UI) frames. I frames numbered up to and including N(R)-1 are acknowledged. I frame N(R) and any subsequent I frames received, if any, are not acknowleaged; the acceptance status of these frames will be indicated in subsequent exchanges.

A Secondary station receiving an RNR frame when in the process of transmitting (i.e., a TWS station) is to stop transmitting at the earliest possible time by completing or aborting the frame in process.

The Primary station may use the RNR command with the Poll bit set to "1" to obtain the receive status of a Secondary station, The Secondary response will be either RR, RNR, or a U frame with the Final bit set to "1".

See Section 8.1, Busy Condition, for further details on RNR.

7.2.3 Reject, REJ, Command and Response

The Reject, REJ, is used by the Primary or Secondary to request retransmission of I frames starting with the frame numbered N(R). I frames numbered N(R)-1 and below are acknowledged. Additional I frames pending initial transmission may be transmitted following the retransmitted I frame(s).

Only one REJ exception condition, from a given station to another station, may be established at any given time; another REJ or SREJ may not be transmitted (i.e., actioned) until the first REJ exception condition has been cleared at the sender.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with an N(S) number equal to the N(R) of the REJ command/response.

An REJ maybe used to reset a busy condition that was initiated by the transmission of RNR. See Section 7.2.2.

See Section 8.2 for sequence error recovery protocols.

7.2.4 Selective Reject, SREJ, Command and Response

The Selective Reject, SREJ, is used by the Primary or Secondary to request retransmission of the single I frame numbered N(R). I frames up to and including N(R)-1 are acknowledged.

The SREJ exception condition is cleared (reset) upon receipt of an I frame with an N(S) number equal to the N(R) of the SREJ command/response.

After a station transmits a SREJ it may not transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared. (To do so would acknowledge as correctly received all I frames up to and including N(R)-1, where N(R) is the sequence number in the second SREJ or REJ.)

I frames that may have been transmitted following the I frame indicated by the SREJ command/response are not retransmitted as the result of receiving a SREJ. Additional I frames pending initial transmission may be transmitted following the retransmission of the specific I frame requested by the SREJ.

An SREJ may be used to reset a busy condition that was initiated by the transmission of RNR. See Section 7.2.2.

See Section 8.2 for sequence error recovery protocols.

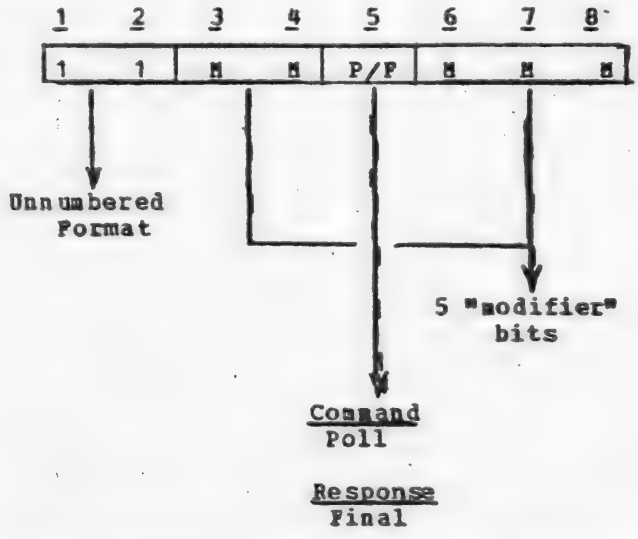
7.3 Unnumbered Format, U, Commands and Responses

Unnumbered, U, commands and responses are used by the Primary and Secondary to extend the number of link supervisory functions. U Frames do not increment the Send Sequence Numbers N(S) at either the transmitting or receiving station. Five "modifier" bits are defined which allow up to 32 additional supervisory functions.

The encoding of the U command/response control field is:

Unnumbered Format
Control Field Bits

First Bit Transmitted



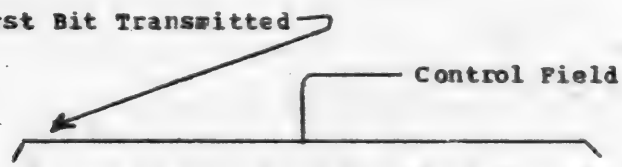
See Section 6.1 for description of the P/F bit operation.

7.4 Unnumbered Format Commands

Unnumbered Format commands are grouped according to the function performed:

- Mode-setting commands: SNRM, SARM, SNRME, SARME, SIM, DISC
- Information transfer commands: UI, UP
- Recovery commands: RSPR
- Miscellaneous commands: USER0, USER1, USER2, USER3, XID

The following U commands are defined; other commands may be defined in the future if required. All bit encodings not defined are reserved.



1	2	3	4	5	6	7	8	
1	1	0	0	P	0	0	1	SNRM Command
1	1	1	1	P	0	0	0	SARM Command
1	1	1	1	P	0	1	1	SNRME Command
1	1	1	1	P	0	1	0	SARME Command
1	1	1	0	P	0	0	0	SIM Command
1	1	0	0	P	0	1	0	DISC Command
1	1	0	0	P	0	0	0	UI Command
1	1	0	0	P	1	0	0	UP Command
1	1	1	0	P	0	0	1	RSPR Command
1	1	0	1	P	0	0	0	USER0 Command
1	1	0	1	P	0	0	1	USER1 Command
1	1	0	1	P	0	1	0	USER2 Command
1	1	0	1	P	0	1	1	USER3 Command
1	1	1	1	P	1	0	1	XID Command

See Section 6.1 for description of the P bit operation.

The SNRM, SARM, SNRME, SARME, SIM, RSPR, and DISC commands require the Secondary to acknowledge acceptance by responding with a single Unnumbered Acknowledgement, UA, frame at the first respond opportunity. The Secondary station transmission of a UA response following the receipt

of one of these commands takes precedence over any other responses which may be pending at the Secondary. If more than one of these U commands is received by a Secondary prior to a respond opportunity, a single UA response is transmitted that is referenced to the first such command received; i.e., any additional I, S or U commands subsequently received are monitored only to detect the next respond opportunity and then discarded.

The respond opportunity at the Secondary is determined by the mode setting command received (i.e., the mode to which the Secondary is directed dictates when the response is transmitted).

1. upon receipt of a SNRM or SNRME command with the P bit set to "1", the Secondary responds with a single UA frame with F bit set to "1"; if the SNRM or SNRME P bit is set to "0", the Secondary waits until a command frame with P bit set to "1" is received and then responds with a single UA frame with the F bit set to "1", or until a UP command (with P bit set to "0") is received and then responds with a single UA frame with the F bit set to "0".

2. upon receipt of a SARM or SARME command with or without the P bit set to "1" the Secondary will transmit a single UA frame:

   a. upon detection of an Idle Link State in TWA operation

   b. immediately in TWS operation.

   The UA frame will have the F bit set to "1" if the command has the P bit set to "1".

3. Upon receipt of a SIM or a DISC command the Secondary will respond with a single UA frame per its system defined respond opportunity; i.e., a given Secondary is system defined to always use the normal mode response opportunity or the asynchronous mode response opportunity.

NOTE: The protocol defined here requires that the Primary station restrict the transmission of U commands which require UA responses so that only one such command is

outstanding (not acknowledged) to any given Secondary at any given time. This eliminates the requirement for the Secondary to queue responses and prevents any ambiguity relative to the meaning of the UA response.

A TWA Secondary station, following the receipt of one of these U commands, is restricted to transmitting a single UA response frame. A TWS Secondary station which is transmitting concurrent to the receipt of one of these U commands will initiate transmission of a single UA response frame at the first respond opportunity. The Secondary may continue transmission following return of the UA response as appropriate to its respond mode.

7.4.1 Mode-Setting Commands

Mode-setting commands are used by the Primary to reset or change the mode of the addressed Secondary. Once established a mode remains in effect at a Secondary until the next mode-setting command is received and actioned.

7.4.1.1 Set Normal Response Mode, SNRM, Command

The SNRM command is used to place the addressed Secondary station in the NRM where all control fields are one octet in length. No information field is permitted with the SNRM command.

The Secondary station confirms acceptance of SNRM by transmission of a UA in the unextended control field format. Upon acceptance of this command the Secondary station send and receive counts are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SNRM indicates a reset of a Primary busy condition initiated by the transmission of RNR. See Section 7.2.2.

7.4.1.2 Set Asynchronous Response Mode, SARM, Command

The SARM command is used to place the addressed Secondary station in ARM where all control fields are one octet in length. No information field is permitted with the SARM command.

The Secondary confirms acceptance of SARM by the transmission of a UA response in the unextended control field format. Upon acceptance of this command the Secondary station send and receive sequence counts are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SARM indicates a reset of a Primary busy condition initiated by the transmission of RNR. See Section 7.2.2.

7.4.1.3 Set Normal Response Mode Extended, SNRME, Command

The SNRME command is used to place the addressed Secondary station in NRME where all control fields will be two octets in length as defined in Section 5.2.2. No information field is permitted with the SNRME command.

The Secondary station confirms acceptance of SNRME by transmission of a UA response in the extended control field format. Upon acceptance of this command the Secondary send and receive counts are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SNRME indicates a reset of a Primary busy condition initiated by the transmission of RNR. See Section 7.2.2.

7.4.1.4 Set Asynchronous Response Mode Extended, SARME, Command

The SARME command is used to place the addressed Secondary station in ARME where all command/response control fields will be two octets in length as defined in Section 5.2.2. No information field is permitted with the SARME command.

The Secondary station confirms acceptance of SARME by transmission of a UA response in the extended control field

format. Upon acceptance of this command the Secondary send and receive counts are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SABME indicates a reset of a Primary busy condition initiated by the transmission of RNR. See Section 7.2.2.

7.4.1.5 Set Initialization Mode, SIM, Command

The SIM command is used to cause the addressed Secondary to initiate a station-specified procedure(s) to initialize its link level control functions (e.g., accept a new program or update operational parameters). No information field is permitted with the SIM command.

The Secondary station confirms acceptance of SIM by transmission of a UA response. Upon acceptance of this command the Secondary station send and receive sequence numbers are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged.

7.4.1.6 Disconnect, DISC, Command

The DISC command is used in switched networks to perform a physical disconnect; i.e., cause the addressed station to go "on-hook". It is also used in non-switched networks to perform a logical disconnect; i.e., inform stations that the Primary is suspending operation with that Secondary station. No information field is permitted with the DISC command.

Prior to actioning the command the Secondary confirms acceptance of DISC by the transmission of a UA response. The respond opportunity after receipt of DISC is dependent upon the response operation (Normal or Asynchronous) the Secondary assumes during disconnect and is system defined for any given Secondary. The respond opportunities are defined in Section 6.1 and 6.2. Upon actioning this command the Secondary station is placed in the unextended (i.e., single octet) control field mode.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged.

7.4.2 Unnumbered Information Transfer Commands

Unnumbered information transfer commands are used to exchange frames containing information.

7.4.2.1 Unnumbered Information, UI, Command

The UI command is used to transfer an information field across a link to a Secondary or group of Secondaries without impacting the Secondary I format sequence numbers, N(S) and N(R). Reception of the UI frame is not sequence number verified, therefore the information field may be lost if a link exception occurs during transmission of the UI, or duplicated if an exception occurs during any reply to the UI. Examples of UI frame information are status, operation interruption, temporal data (e.g., time-of-day), or link initialization parameters.

See Appendix B, 7.4.2.1 for additional explanatory information.

7.4.2.2 Unnumbered Poll, UP, Command

The UP command is used to solicit response frames from a single Secondary (Individual Poll) or from a group of Secondaries (Group Poll), by establishing a logical operational condition that exists at each addressed Secondary for one respond opportunity. (In the case of a Group Poll, the mechanism employed to control (schedule) the response transmissions (to avoid simultaneous transmissions) is considered to exist and is not defined in this standard.) Secondaries receiving UP with a group address will respond in the same manner as when addressed using an individual address. The response frame(s) will contain the sending Secondary's individual address, plus N(S) and N(R) numbers as required by the particular responses. (The continuity of each Secondary's N(S) count will be maintained.) The UP command does not acknowledge receipt of any response frames that may have been previously transmitted by the Secondary(s). No information field is permitted with the UP command.

A Secondary which receives a UP with the P bit set to "1" will respond (at its respond opportunity and consistent with its mode of operation) with a frame which has the P bit set to "1".

A Secondary which receives a UP with the P bit set to "0" may or may not respond depending on the status of the Secondary; Secondary responses sent in reply to this command will have the P bit is set to "0" in all frames of each Secondary's response. A Secondary will respond to a received UP which has the P bit set to "0" when: 1) it has an I/UI frame(s) to send, 2) it has received but not acknowledged an I frame(s) 3) it has experienced an exception condition or change of status that has not been reported, 4) it has a status that must be reported again (e.g., DM, CMDR).

7.4.3 Unnumbered Recovery Commands

Unnumbered recovery commands are used to facilitate the link level exception recovery protocol.

7.4.3.1 Response Reject, RSPR, Command

The RSPR command is used to report an error not recoverable by retransmission of the identical frame; i.e. one of the following conditions resulted from the receipt of an error free frame from the Secondary station:

1. The receipt of a response that is invalid or not implemented.

2. The receipt of an I/UI response with an information field which exceeded the maximum established length. (An RSPR condition will not be established upon receipt of an XID response frame with an information field that exceeds the maximum established storage capability of the Primary.)

3. The receipt of a response frame having an invalid N(R) number. (See 7.5.3.1 for definition of an invalid N(R) number.)

A Status field immediately following the control field is included with this command to provide the reason for the

RSPR. Refer to Section 7.5.3.1 for the size and content of the Basic Status field and Extended Status field except substitute "RSPR" for "CMDR", "response reject" for "command reject", and "Primary station" for "Secondary station".

The Secondary will, at the first respond opportunity following the receipt of RSPR, transmit 1) a UA, response to indicate it will take action to correct the RSPR condition, or 2) a CMDR, response to indicate that either no corrective action will be taken or that the RSPR command is not implemented.

RSPR with an on all zeros information field (including w,x,y, and z all equal to zero) indicates an unspecified rejection of a response frame.

See also Section 8.4, Command-Response Reject.

7.4.4 Miscellaneous Commands

7.4.4.1 Exchange Identification, XID, Command

The XID command is used to cause the addressed Secondary station to identify itself, and optionally to provide Primary station identification to the addressed Secondary. An information field is optional with the XID command; if present the information field will be the Primary station ID. If no information field is present with the XID command the Primary station is scliciting the addressed Secondary station ID. A Secondary in any mode receiving an XID command will transmit an XID response unless 1) a set mode response (UA) is pending, or 2) a CMDR condition exists.

An RSPR condition will not establish if the received XID has an information field which exceeds the maximum established storage capability of the Primary.

7.4.4.2 User-Defined Commands (USER0, USER1, USER2, USER3)

Four User-Defined commands are specified to permit the implementer to define special system-dependent functions that do not have general applicability. The User-Defined commands are USER0, USER1, USER2, and USER3.

7.5 Unnumbered Responses

Unnumbered responses are grouped according to the function performed:

- Mode-setting responses: UA, DM, RIM
- Information transfer responses: UI
- Recovery responses: CMDR
- User-defined responses: USER0, USER1, USER2, USER3

The following Unnumbered responses are defined; other responses may be defined in the future if required. All bit encodings not defined are reserved.

Control Field Bits								
1	2	3	4	5	6	7	8	
1	1	0	0	P	1	1	0	UA Response
1	1	1	1	P	0	0	0	DM Response
1	1	0	0	P	0	1	0	RD Response
1	1	1	0	P	0	0	0	RIM Response
1	1	0	0	P	0	0	0	UI Response
1	1	1	0	P	0	0	1	CMDR Response
1	1	0	1	P	0	0	0	USER0 Response
1	1	0	1	P	0	0	1	USER1 Response
1	1	0	1	P	0	1	0	USER2 Response
1	1	0	1	P	0	1	1	USER3 Response
1	1	1	1	P	1	0	1	XID Response

See Section 6.1 for description of the P bit operation

7.5.1 Mode-Setting Responses

Mode-setting responses are used by the Secondary to request transmission of, or to respond to the mode-setting commands of the Primary.

7.5.1.1 Unnumbered Acknowledge, UA, Response

The UA response is used to acknowledge the receipt and acceptance of the SNRM, SARM, SNRME, SARME, SIM, DISC, and RSPR Unnumbered commands defined in Sections 7.4.1 and 7.4.3. The UA response is transmitted in the basic or the extended control field format as directed by the received

Unnumbered command. No information field is permitted with the UA response. (See Section 7.4 for additional details)

7.5.1.2 Disconnected Mode, DM, Response

The DM response is used to report a non-operational status where the Secondary is logically disconnected from the link; i.e., the Secondary is, per system definition, in NDM or ADM. (See Section 6.2 for details.)

The DM response is sent by a Secondary in NDM or ADM (or equivalent state) to request the Primary to issue a set mode command, or, if sent in response to the reception of a set mode command, to inform the Primary that the Secondary is still in NDM/ADM and cannot action the set mode command. On a switched network where the call is initiated by a Secondary DM is sent to request a set mode command. On a non-switched line a Secondary in ADM may send the DM response at any respond opportunity. No information field is permitted with the DM response.

A Secondary in NDM or ADM will monitor received commands (other than those that reset the disconnected mode) only to detect a respond opportunity in order to (re)transmit DM (or RIM if initialization is required); i.e., no transmissions are accepted until the disconnected mode is reset by the receipt of SNRM, SARM, SNRME, SARME, or SIM.

See Appendix C, Example 5.5.

7.5.1.3 Request Disconnect, RD, Response

The RD response is used to indicate to the Primary that the Secondary wishes to be placed in disconnected mode (NDM or ADM). RD may be sent asynchronously if the Secondary is in ARM, or if in NRM as a response to a command with the P bit set to "1". A Secondary which has sent an RD response and receives any non DISC frame(s) must accept the command frame(s) if it is able to do so. If the Secondary accepts the non DISC command frame(s) it follows the normal ADCCP elements of procedures to respond to the Primary commands. Secondary acceptance of non DISC frames after having issued an RD response cancels the RD response. If the Secondary still wants to be placed in disconnected mode (NDM or ADM) which it must re-issue the RD response. A Secondary cannot accept non DISC commands frame(s) due to internal problems may

respond with RD again. No information field is permitted with the RD response.

7.5.1.4 Request Initialization Mode, RIM, Response

The RIM response is used to request the SIM command. A Secondary which has established a RIM condition will monitor any subsequently received commands (other than SIM or DISC) only to detect a respond opportunity to (re)transmit RIM; i.e., no transmissions are accepted until the RIM condition is reset by the receipt of SIM or DISC. No information field is permitted with the RIM response.

7.5.2 Unnumbered Information Transfer Responses

Unnumbered information transfer responses are used to exchange frames containing information.

7.5.2.1 Unnumbered Information, UI, Response

The UI response is used to transfer an information field across a link without impacting the Secondary I format sequence numbers, N(S) and N(R). Reception of the UI frame is not sequence number verified, therefore the information field may be lost if a link exception occurs during transmission of the UI, or duplicated if an exception occurs during any reply to the UI. Examples of UI frame information are status, operation interruption, temporal data, and link initialization parameters.

7.5.3 Unnumbered Recovery Responses

Unnumbered recovery responses are used to facilitate the link level exception recovery protocol.

7.5.3.1 Command Reject, CMDR, Response

The CMDR response is used to report an error condition not recoverable be retransmission of the identical frame; i.e., one of the following conditions resulted from the receipt of an error free frame from the Primary station:

1 the receipt of a command that is invalid or not implemented.

2 the receipt of an I/UI frame with an information field which exceeded the maximum established length. (A CMDR condition will not be established upon receipt of an XID command frame with an information field that exceeds the maximum established storage capability of the Secondary.)

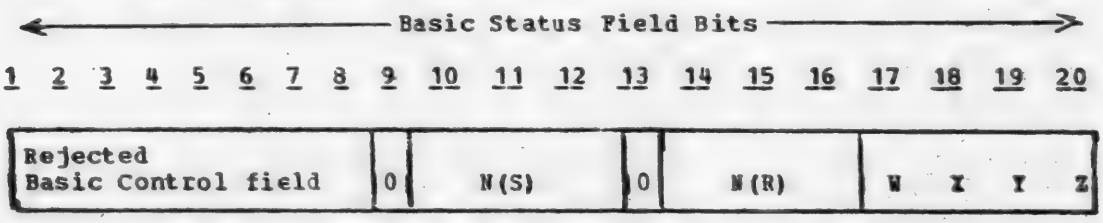
3 the receipt of an invalid N(R) number from the Primary station.

An invalid N(R) is defined as a number which points to an I frame which has previously been transmitted and acknowledged, or to an I frame which has not been transmitted and is not the next sequential I frame pending transmission.

A Secondary in a disconnected mode (NDM or ADM) will not establish a CMDR condition.

CMDR Basic Status Field

A Basic Status Field, which immediately follows the basic control field is returned with this response to provide the reason for the Command Reject Response. The format for the Basic status field is:



First Bit Transmitted

where:

Rejected Control Field is the control field of the received frame which caused the command reject

N(S) is the current N(S) number of the Secondary station

N(R) is the current N(R) number of the Secondary station

w set to "1" indicates the control field received and returned in bits 1 through 8 was invalid or not implemented

x set to "1" indicates the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this command. Bit w must be set to "1" in conjunction with this bit.

y set to "1" indicates the information field received exceeded the maximum established capacity of the Secondary station. This bit is mutually exclusive with bit w above.

z if set to "1" indicates the control field received and returned in bits 1 through 8 contained an invalid N(R) number. This bit is mutually exclusive with bit w above.

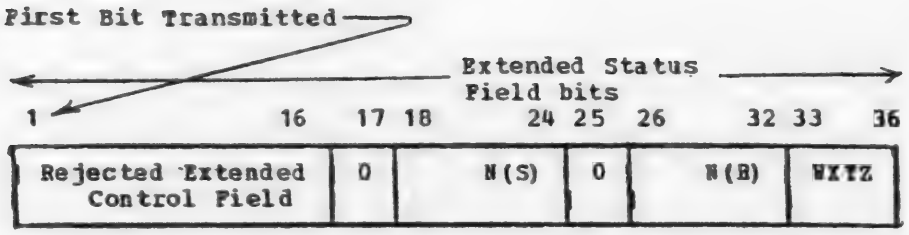
If required, the Status field associated with the CMDR may be padded with zero bits to provide a modulo of the character width being used.

CMDR with an all zeros information field (including w,x,y and z all equal to zero) indicates an unspecified rejection of the command.

See also Section 8.4, Command-Response Reject

CMDR Extended Status Field

The format for the Extended Status field, which immediately follows the extended control field (see Section 5.2.2), returned with the CMDR response is:



7.5.4 Miscellaneous Responses

7.5.4.1 Exchange Identification, XID, Response

The XID response is used to reply to an XID command. An information field containing the Secondary station identification is optionally present with the XID response. A Secondary receiving an XID command will action the XID in any mode unless 1) a set mode response (UA) is pending or 2) a CMDR condition exists.

A CMDR condition will not be established if the received XID command has an information field which exceeds the maximum established storage capability of the Secondary.

On switched networks when the Secondary is the calling station it may use the XID response, which may contain an optional information field, to request an XID exchange. (See Section 10.0 Switched Network Conventions.)

7.5.4.2 User-Defined Responses (USER0, USER1, USER2, USER3)

Four User-Defined responses are specified to permit the implementer to define special system-dependent functions that do not have general applicability. The User-Defined responses are USER0, USER1, USER2, and USER3.

8.0 EXCEPTION CONDITION REPORTING AND RECOVERY

This section specifies the procedures to be observed to effect recovery following the detection/occurrence of an exception condition at the link level. Exception conditions described are those situations that may occur as the result of transmission errors, station malfunction or operational situations.

8.1 Busy Condition

A busy condition occurs when a station temporarily cannot receive, or continue to receive I frames due to internal constraints, e.g., receive buffering limitations. The "busy" condition is reported by transmission of an RNR frame with the N(R) number of the first I frame that is expected. Traffic pending transmission at the busy station may be transmitted prior to or following the RNR. The continued existence of a busy condition must be reported by retransmission of RNR at each P/F frame exchange. See Section 8.1.3, Clearing Busy Condition.

8.1.1 Secondary Receipt of RNR

a. A Secondary transmitting in NRM will upon receipt of an RNR cease transmission at the earliest possible time. The frame in process may be completed or aborted, however transmission must be terminated in the usual manner; i.e., either ended with a frame with the F bit set to "1" (see Example 5.2.1, Appendix C) or going to the Idle Link State. The Secondary may resume transmission of I frames at the next poll command (an RR, REJ, SREJ, or I command frame with the P bit set to "1").

b. A Secondary transmitting in ARM will, upon receipt of an RNR, cease transmitting at the earliest possible time by completing or aborting the frame in process and going to the Idle Link State. If the RNR command frame had the P bit set to "1" the Secondary must transmit a frame with the F bit set to "1" before going to the Idle Link State. See Examples 5.4.1 and 5.4.3 in Appendix C. The Secondary must perform a Response/Command Time-out before resuming asynchronous transmission.

8.1.2 Primary Receipt of RNR

Primary receipt of an RNR indicates that the transmitting Secondary has a busy condition.

8.1.3 Clearing Busy Condition

The busy condition is cleared at the station which transmitted the RNR when the internal constraint ceases.

Clearance of the busy condition is reported to the remote station by transmission of an RR, REJ, or SREJ frame (with or without the P/F bit set to "1"), or by transmitting an I frame with the P/F bit set to "1".

8.2 N(S) Sequence Error

An N(S) sequence exception is established in the receiving station when an I frame received error free (no FCS error) contains an N(S) sequence number that does not agree with the stations N(R) sequence number. The receiving station does not acknowledge (increment its N(R) number) the frame causing the sequence error, or any I frames which may follow, until an I frame with the correct N(S) number is received.

A station which receives one or more valid I frames having sequence errors but otherwise error free will accept the control information contained in the N(R) number and the P/F bit to perform link control functions; e.g., to receive acknowledgement of previously transmitted I frames (via the N(R) number), to cause a Secondary station to respond (P bit set to "1"), and in NRM to detect that the Secondary will terminate transmission (F bit set to "1").

Following the occurrence of a sequence error one of the two following recovery protocols is implemented to achieve recovery. Which protocol is used is dependent upon whether the optional SREJ command/response is implemented by a given Secondary. Both BASIC and SREJ recovery protocols may be used on a link, but only one protocol is used at any given Secondary.

The two recovery protocols are:

a. BASIC Recovery (NB/NAB CLASSES) uses REJ and Poll/Final Bit frame exchange (described in Section 8.2.1); the recovery protocol causes retransmission of the missing I frame which caused the sequence error and all I frames which may have been transmitted following that frame.

b. SREJ Recovery (NS/NAS CLASSES) uses SREJ and REJ commands/responses (described in Section 8.2.2); the recovery protocol causes either retransmission of only the missing I frame which caused the sequence error (SREJ recovery), or retransmission of the missing I frame which caused the sequence error and all I frames which may have been transmitted following that frame (REJ recovery).

NOTE: In these two recovery protocols the exchange of P/F bit frames perform different functions:

1. in BASIC Recovery protocol the receipt of P/F bit frames can initiate retransmission of errored or lost I frames in the same manner as the receipt of a REJ. Retransmission of I frames begins at the N(R) sequence number in the REJ, the N(R) number in the P/F bit frame, or (in the case where the P/F bit is in a U frame) at the N(R) number that exists in the receiver at the time the P/F bit is received. See Appendix B, 8.2 for precautionary note.

2. in SREJ Recovery protocol the receipt of P/F bit frames is used to sense the failure of the first attempt at recovery; i.e., the P/F bit frame exchange detects that a transmitted SREJ or REJ was not correctly received at the remote station and must be retransmitted.

8.2.1 BASIC Recovery Capability (NB/NAB CLASSES)

8.2.1.1 REJ and Poll/Final Recovery

When a station has BASIC recovery capability (i.e. does not have the capability to receive the SREJ command/response) the recovery protocol is initiated by receipt of REJ, by the

exchange of N(R) numbers in Poll/Final frames, or by a system specified Response/Command Time-out; additionally, in TWA data exchange, recovery may be initiated by the receipt of an N(R) number that does not acknowledge all previously transmitted I frames.

8.2.1.2 REJ Recovery

The REJ command/response is primarily used to initiate more timely exception recovery (retransmission) following the detection of a sequence error than is possible by Poll/Final recovery; e.g., in TWS information transfer, if REJ is immediately transmitted upon detection of a sequence error, there is no requirement to wait for a Poll/Final frame exchange. See Examples 3.2.1, 3.3.1, 4.2.2, 4.3.1, 7.1.1 and 7.1.3 in Appendix C.

Only one REJ exception condition is established at any given time and the REJ command/response may be transmitted only one time when an REJ exception condition is established.

A station receiving REJ initiates retransmission of I frames starting with the I frame indicated by the N(R) number contained in the REJ frame.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with a N(S) number equal to the N(R) number of the REJ command/response.

8.2.1.3 Poll/Final Recovery

If, following a sequence error, the REJ command/response is not received (i.e., either not transmitted or due to transmission errors) recovery is initiated by P/F bit exchange. (If no P/F bit exchange occurs, recovery is initiated by detection of an Idle Link State or a Response/Command Time-out.) Following the exchange of Poll/Final frames, sequential transmission of I frames (if available) is initiated starting with any previously transmitted but unacknowledged I frames or, if none, starting with additional I frames not previously transmitted. See Examples 1.2.2, 1.3.2, 2.2.2, 2.3.2, 4.3.3, 4.3.4, 7.1.2, 7.1.4 and 7.2.2 in Appendix C. A station in ARM TWS which has received and actioned a REJ

prior to or concurrent with the receipt of a Poll/Final frame will not additionally initiate Poll/Final recovery.

8.2.1.4 Response/Command Time-Out

Following the transmission of a frame to which a reply is expected, a no-response or lost-response condition is detected by the Response/Command Time-out. (See Section 9.0.) Upon expiration of the time-out function, one or more frames are retransmitted starting with the last N(R) sequence number received. See Examples 1.2.1, 1.2.3, 1.3.1, 1.3.3, 2.1.2, 2.2.1, 2.3.1, 2.3.3, 4.2.1, and 8.2 in Appendix C.

8.2.1.5 Receipt of N(R) in TWA Data Exchange

In TWA data exchange, when P/F bit frames are lost, in error or not exchanged, the receipt of an N(R) number which does not acknowledge all previously transmitted I frames will initiate (at the next respond opportunity) sequential retransmission of I frames not acknowledged. See Example 2.2.3 in Appendix C.

8.2.2 SREJ Recovery Capability (NS/NAS CLASSES)

8.2.2.1 SREJ/REJ Recovery

The SREJ command/response is primarily used to initiate more efficient error recovery by requesting the retransmission of a single I frame following the detection of a sequence error rather than the retransmission of the I frame requested plus all additional I frames which may have been subsequently transmitted. To improve transmission efficiency it is recommended that the SREJ command/response be transmitted as the result of the detection of a sequence error where only a single I frame is missing (as determined by receipt of the out-of-sequence N(S) number).

When SREJ/REJ error recovery protocol is used, retransmission of I frame(s) is initiated only upon recieipt of either a SREJ or REJ command/response as described below. If the SREJ or REJ is not received, or is received incorrectly by the remote station, it must be retransmitted before initiating error recovery.

8.2.2.2 SREJ Recovery

When an I frame sequence error is detected, the SREJ is transmitted at the earliest possible time. Although multiple SREJ (or multiple SREJ and one REJ) exception conditions may exist within a station only one exception recovery is actioned at any given time; i.e., after a station starts the SREJ recovery procedure it may not begin a second SREJ or a REJ recovery procedure until the first error condition has been cleared. For a given error condition the SREJ command/response is transmitted only one time in each Poll/Final frame exchange.

The SREJ exception condition at the sender is cleared (reset) upon the receipt of an I frame with an N(S) number equal to the N(R) of the SREJ command/response i.e., the missing I frame.

See Examples 3.2.2, 3.3.2, 4.2.3, 4.3.2, 7.2.1 and 7.2.3 in Appendix C.

8.2.2.3 REJ Recovery

In the event the sequence error is caused by two or more sequential I fames not being received, as determined by the received N(S) numbers, it is recommended that the REJ command/response be transmitted.

Only one REJ exception condition is established at any given time. (Note that there may be one or more SREJ exception conditions pending when the REJ exception condition occurs.) A station receiving REJ initiates retransmission of I frames starting with the I frame indicated by the N(R) number contained in the REJ frame.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with an N(S) number equal to the N(R) of the REJ command/response.

NOTE: The following Examples in Appendix C have been specified for BASIC Recovery capability (Section 8.2.1, REJ Recovery) but also apply to the use of REJ in stations with SREJ Recovery capability: 3.2.1, 3.3.1, 4.2.2, 4.3.1, 7.1.1, and 7.1.3. in Appendix C.

8.2.2.4 Retransmission of SREJ or REJ

In the event the SREJ or REJ command/response is transmitted but not received by the remote station (i.e., due to a transmission error), it must be retransmitted following detection that it was not received. This detection will occur either at the exchange of P/F bit frames (as described below) or by a Response/Command Time-out. In either case the SREJ or REJ command/response is retransmitted so that the proper recovery action may be executed.

For example, in the case where a SREJ (or REJ) is transmitted by a Secondary but is not received correctly by the Primary, the Secondary senses the SREJ (or REJ) must be retransmitted when, following transmission of a response frame with the Final bit set to "1" concurrent with or after the SREJ (or REJ), the requested I frame(s) is not received by the Secondary prior to or concureent with the receipt of a command frame with the Poll bit set to "1". In other words, since the Secondary transmitted the SREJ (or REJ) concurrent with or before sending the response frame with the Final bit set to "1", then the I frame(s) requested by SREJ (or REJ) should be received prior to or concurrently with the next command frame with Poll bit set to "1". (See example 7.2.4 in Appendix C where SREJ is transmitted prior to response frame I3,1F but the requested I frame is not received prior to command frame I6,4P.)

In like manner if a Primary which has transmitted a SREJ (or REJ) does not receive the requested I frame(s) prior to or concurrent with receiving the response frame with the Final bit set to "1" which is itself in reply to the first command frame with the Poll bit set to "1" concurrent with or following the SREJ, it will retransmit the SREJ (or REJ).

In the event the remote station, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frame(s) in a sequence of I frames it will not detect an out-of-sequence exception condition and, therefore, will not transmit SREJ/REJ. The station which transmitted the unacknowledged I frame(s) will, following the completion of a system specified timeout period take appropriate recovery action to determine the point where retransmission must begin.

In the event an SREJ is transmitted but not received (or is received in error and discarded) the station that transmitted the SREJ may convert the SREJ to REJ when again reporting the exception condition (e.g., if additional transmission errors have occured since the SREJ was first transmitted).

8.3 FCS Error

Any frame received with an FCS error is not accepted by the receiving station and is discarded. At the Secondary no action is taken as the result of that frame.

8.4 Command-Response Reject

A command-response reject exception condition is established upon the receipt of an error free frame which contains an invalid command/response in the control field, an invalid frame format, an invalid N(R) number or an information field which exceeded the maximum established storage capability.

At the Primary station this exception condition is subject to recovery/resolution at a higher function level.

At the Secondary station the exception condition is reported by transmitting a CMDR response to the Primary station for appropriate action. Once a Secondary station has established a CMDR exception any additional commands (other than those that reset the CMDR exception condition) subsequently received are examined only with regard to the state of the N(R) number and P bit; i.e., only to update the acknowledgement of I frames previously transmitted and to detect a respond opportunity to retransmit CMDR. No additional transmissions are accepted or actioned until the condition is reset by the receipt of a SNRM, SARM, SNRME, SABME, SIM, or DISC.

At the Secondary station the receipt of a Response Reject, RSPR is subject to recovery/resolution at a higher function level.

9.0 RESPONSE/COMMAND TIME-OUT

In order to detect a no-response or lost-response condition, each Primary shall provide a response time-out function. Also, in Asynchronous mode of operation in order to detect a no-response or lost-response condition, each Secondary shall provide a command time-out function.

9.1 Normal Response Mode

The transmission of any command with the P bit set to "1" requires a response and therefore starts the time-out function. (NOTE: No more than one poll may be outstanding at one time.)

The time-out function shall be restarted upon receipt of a valid frame.

The time-out function shall be stopped upon receipt of the expected response.

Expiration of the time-out function shall initiate appropriate recovery action.

The duration of the time-out function is system dependent and subject to bilateral agreement.

9.2 Asynchronous Response Mode

The transmission of any command with the P bit set to "1" requires a response and therefore starts the time-out function.

The time-out function shall be stopped upon receipt of a valid frame with the F bit set to "1".

Expiration of the time-out function shall initiate appropriate recovery action.

The duration of the time-out function is system dependent and subject to bilateral agreement.

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10.0 SWITCHED NETWORK CONVENTIONS

Stations connected to a switched communications network may be capable of operation as primary stations only, as secondary stations only, or as either primary or secondary stations. The capabilities of the called station must be known at the calling station and the calling station must operate accordingly. If the called station is capable of operating either as a Primary or as a Secondary it

1) will implement the XID command and response, and

2) will determine which type of link control (Primary or Secondary) to invoke by recognition of either the remote station link address or identification (XID).

The calling or called station will initiate the transmission interchange first depending on the characteristics of the transmission network. When initiated by the secondary, it sends a single unsolicited Supervisory or Unnumbered response. When initiated by the primary, it sends any appropriate command with an appropriate address.

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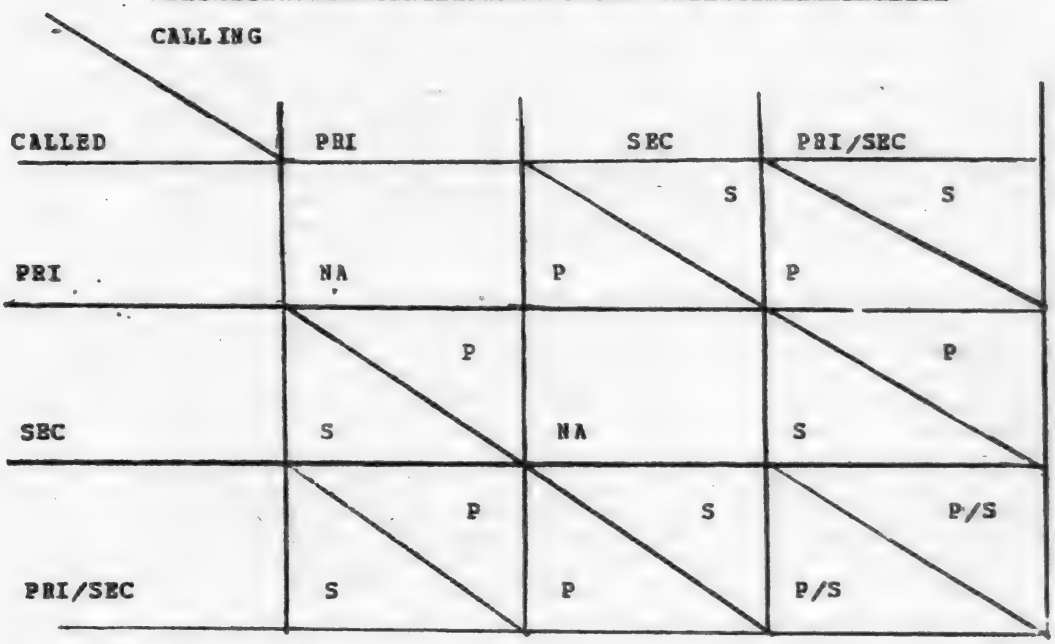
ASSUMED PRIMARY/SECONDARY ROLES ON SWITCHED NETWORK



Pri = P = Primary
Sec = S = Secondary
Pri/Sec = P/S = Primary or Secondary
NA = Not Applicable

Figure 10-1

11.0 CLASSES OF PROCEDURES

All classes of procedures use the two frame formats as defined in Section 3.0 FRAME STRUCTURE. In addition, all procedures assume that the links include primary and secondary link controllers. Primary link controllers transmit commands (in frames with or without data), and secondary link controllers receive the command frames and transmit responses (in frames with or without data). The primary link controller is responsible for determining which commands to send, within the constraints of the standard.

Procedure differences, based on overall system consideration (e.g., network configuration, traffic management, etc.) are accommodated by defining two modes of operation - Asynchronous and Normal - and by defining various classes of procedures that utilize the capabilities of these modes together with the exception recovery characteristics specified within the standard. Individual classes implement a prescribed subset of the commands and responses defined in Section 7.0, COMMANDS AND RESPONSES. ("Implement" is defined at the Primary as the ability to receive all responses in the prescribed subset, and at the Secondary as the ability to receive all commands in the prescribed subset.)

APPENDIX B, ADDITIONAL INFORMATION, provides examples that illustrate how a point-to-point (P-P) Primary-to-Secondary (P-S) configuration(s) (described below in Section 11.1, and 11.2 Primary-to-Secondary Classes of Procedures) may be employed to yield balanced control or near-balanced control operation. These capabilities are in addition to the P-P Balanced Control Classes of Procedure (previously called "Primary/Primary") defined in Section 11.3.

11.1 Normal Response Mode (NRM) Primary to Secondary (P-S) Classes of Procedure

These classes of procedure are applicable to point-to-point (P-P) and multipoint (MP) link configurations. The Secondary station may transmit a frame or frames only as a result of the receipt of an appropriate command frame as described in Section 6.1.1, Normal Response Mode.

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11.1.1 NB CLASS: Normal Response Mode - BASIC Exception Recovery Procedure

Stations operating in this mode may use the REJ command/response to solicit retransmission of any frame detected in error. The subsequent retransmission will consist of the frame in error plus any previously transmitted frames in accordance with Section 8.2.1.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SNRM	UA
DISC	CMDR
RSPR	

11.1.2 NS CLASS: Normal Response Mode - SREJ Exception Recovery Procedure

Stations operating in the Normal Mode with Selective Reject capability can request retransmission of a single specified I frame without requiring retransmission of previously transmitted following frames; See section 8.2.2.

The following commands and Responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SREJ	SREJ
SNRM	UA
DISC	CMDR
RSPR	

11.2 Normal and Asynchronous Response Mode (NRM and ARM) Primary-to-Secondary (P-S) Classes of Procedure

11.2.1 NAB CLASS: Normal and Asynchronous Response Mode - BASIC Exception Recovery Procedure

In this class, in addition to the operation described in Section 11.1.1 above, the Primary station can condition a Secondary station(s) to transmit frames at any time independent of further action by the Primary; see Section 6.2, Asynchronous Response Mode.

The following commands and Responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SNRM	UA
SARM	CMDR
DISC	
RSPR	

11.2.2 NAS CLASS: Normal and Asynchronous Response Mode - SREJ Exception Recovery Procedure

Stations operating in the Normal Mode with Asynchronous capability and with Selective Reject Operation can request retransmission of a single, specified information frame as described in Section 8.2.2.

The following commands and Responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SREJ	SREJ
SNRM	UA
SARM	CMDR
DISC	
RSPR	

11.3 Balanced Control Classes of Procedures (previously called "Primary/Primary")

These Balanced Control classes of procedures are restricted to point-to-point two-way simultaneous (P-P TWS), switched or non-switched transmission facility. See Figure 11-1. Each station is responsible for correction of errors associated with the traffic it originates. Each station can transmit frames at any time independent of action by the other station. Stations operating according to these classes of procedures use the Asynchronous Response Mode of operation. Each station maintains only one sequence number for all I frames transmitted and only one sequence number for all I frames accepted.

All Command frames specify the receiving station address. All Response frames specify transmitting station address.

The N(R) number in both Information and Supervisory formats indicates that the station transmitting the N(R) has

correctly received all information format frames numbered up to and including N(R)-1. See examples 8.1 and 8.2 in Appendix C.

11.3.1 BCB CLASS: Balanced Control - BASIC Exception Recovery Procedure

Stations operating in this class use the REJ command/response to solicit retransmission of any frame(s) detected in error. The subsequent retransmission will consist of the frame in error plus any previously transmitted following frames in accordance with Section 8.2.1.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
	REJ
RSPB	CMDR
SARM	UA
SARME	
DISC	

11.3.2 BCS CLASS: Balanced Control, SREJ Exception Recovery Procedure

Stations operating in this class have the option to request retransmission of a single, specified information frame without requiring retransmission of previously transmitted following frames, in accordance with Section 8.2.2.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
	REJ
	SREJ
RSPR	CMDR
SARM	UA
SARME	
DISC	

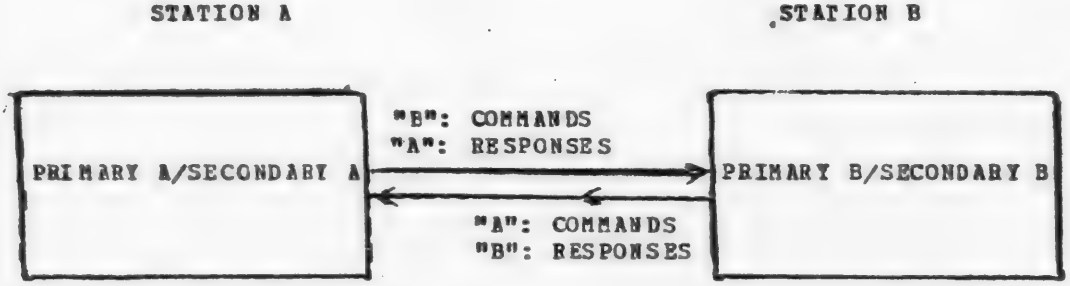

FIGURE 11-1

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12.0 FRAME CHECK SEQUENCE (FCS) GENERATION AND CHECKING

This section specifies the FCS generation and checking requirements. These requirements are formulated to detect frame length changes due to erroneous addition or deletion of zero bits at the end of the frame as well as to detect errors introduced within the frame.

12.1 FCS Generation

The equations for FCS generation are:

$$\frac{X^{16} G(x) + X^{k} L(X)}{P(X)} = Q(X) + \frac{R(X)}{P(X)} \quad \text{and,}$$

$$FCS = L(X) + R(X) = R(X),$$

The division is modulo 2 and,

$L(X) = X^{15} + X^{14} + X^{13} + X^{12} + X^{11} + X^{10} + X^{9} + X^{8} + X^{7} X^{6} + X^{5} + X^{4} + X^{3} + X^{2} + X^{1} + 1,$

$R(X)$ = The remainder which is of degree less than 16.

k = The number of bits represented by $G(X)$,

$P(X)$ = The CCITT V.41 generator polynomial ($X^{16} + X^{12} + X^{5} + 1$), and

$G(X)$ = The message polynomial. It includes the contents of the address, control and information fields, excluding the zero bits inserted for transparency (see Section 3.7).

The generation of the remainder $R(X)$ differs from that used in conventional check sequence generation by the presence of the $X^{k} L(X)$ term in the generation equation. When the FCS generation is by the usual shift register technique, the $X^{k} L(X)$ term is added in either of two ways:

1. Preset the shift register to all ones rather than to all zeros as in conventional generation procedures. Otherwise, shift the data ($G(X)$) through the register as in conventional procedures, or,

2. Invert the first 16 bits of G(X) before shifting into the register and shift the remaining part of G(X) through uninverted. This requires that G(X) contain at least 16 bits.

Whether 1 or 2 is used, the shift register contents, after shifting through G(X), is R(X). These contents are inverted bit-by-bit and transmitted as the FCS sequence.

The transmitted sequence is always (in algebraic notation):

$$M(X) = X^{16} G(X) + FCS.$$

12.2 FCS Checking

The received sequence will be denoted M*(x), which differs from M(x) if transmission errors are introduced. The checking process always involves dividing the received sequence by P(x) and testing the remainder. Direct division, however, does not yield a unique remainder and it is expected that in most cases the received sequence will be modified for checking purposes by addition of terms which will cause the division to yield such a unique remainder when M*(x) = M(x), i.e., when the frame is error free.

Two classes of checking equations are given below:

1. $$\frac{X^{\gamma}[M^*(x) + X^k L(x)]}{P(x)} = Q(x) + \frac{R(x)}{P(x)}$$

In this case the unique remainder is the remainder of the division $X^{\gamma}\frac{L(x)}{P(x)}$

When $\gamma = 0$ the remainder is L(x) (16 ones).
When $\gamma = 16$ the remainder is $X^{12} + X^{11} + X^{10} + X^8 + X^3 + X^2 + X + 1$ (0001110100001111 X^{15} through X^0 respectively)

2. $$X^{\gamma}\left[\frac{M^*(x) + (X^k + 1) L(x)}{P(x)}\right] = Q(x) + \frac{R(x)}{P(x)}$$

In this case the unique remainder is always zero regardless of the value of γ.

Shift register implementation of the above equations normally use $\gamma = 16$ (pre-multiplication). When this is the

case, the added term X L(x) in both 1 and 2 is added by either inverting the first 16 received bits of N*(X) before shifting them through the checking register or by presetting the register to all 1's and shifting all of N*(X) through normally. Thus the receiver action on the leading portion of a frame is the same with either 1 or 2.

The + 1 of the term (X + 1)L(x) of the generation equation of 2 is added by inverting the FCS. This implies a 16 bit storage delay by the FCS function at the receiver since the location of the FCS is not known until the closing flag is received.

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APPENDIX A - GLOSSARY

ABORT: A function invoked by a sending (PRIMARY or SECONDARY) station causing the recipient to discard (and ignore) all bit sequences transmitted by the sender since the preceding FLAG SEQUENCE.

ACCEPT: The condition assumed by a (PRIMARY or SECONDARY) station upon accepting a correctly received FRAME for processing.

ADCCP: Advanced Data Communication Control Procedures.

ADDRESS FIELD (A): The sequence of eight (or any multiple of eight if extended) bits immediately following the opening FLAG of a FRAME identifying the SECONDARY station sending (or designated to receive) the FRAME.

ADDRESS FIELD EXTENSION: Enlarging the ADDRESS FIELD to include more addressing information.

BASIC STATUS: A SECONDARY STATION's capability to send or receive a FRAME containing an INFORMATION FIELD.

COMMAND: The content of the CONTROL FIELD, of a COMMAND FRAME sent by the PRIMARY instructing the addressed SECONDARY to perform some specific LINK LEVEL function.

COMMAND FRAME: All FRAMES that may be transmitted by the PRIMARY are referred to as COMMAND FRAMES.

CONTROL FIELD (C): The sequence of eight (or sixteen if extended control field) bits immediately following the ADDRESS FIELD of a FRAME. The content the CONTROL FIELD is interpreted by the receiving:

(a) SECONDARY, designated by the ADDRESS FIELD, as a COMMAND instructing the performance of some specific function.

(b) PRIMARY, as a RESPONSE from the SECONDARY, designated by the ADDRESS FIELD, to one or more COMMANDS.

CONTROL FIELD EXTENSION: Enlarging the CONTROL FIELD to include additional control information.

(a) Is terminated by an ABORT Sequence, or

(b) Contains less than 32 bits before an apparent ending FLAG SEQUENCE is detected.

LINK LEVEL: The conceptual level of control or processing logic existing in the hierarchical structure of a (PRIMARY or SECONDARY) station that is responsible for maintaining control of the DATA LINK. The LINK LEVEL functions provide an interface between the station HIGH LEVEL logic and the DATA LINK; these functions include (transmit) bit injection and (receive) bit extraction, ADDRESS/CONTROL FIELD interpretation, COMMAND/RESPONSE generation, transmission and interpretation, and FRAME CHECK SEQUENCE computation and interpretation.

PRIMARY: That portion of the Primary station responsible for control of the DATA LINK. The PRIMARY generates COMMANDS and interprets RESPONSES. Specific responsibilities assigned to the PRIMARY include:

(a) Initialization of (data and control) information interchange

(b) Organization and control of data flow

(c) Retransmission control

(d) All recovery functions at the LINK LEVEL

RESPOND OPPORTUNITY: The LINK LEVEL logical control condition during which a given SECONDARY may transmit a RESPONSE FRAME(s).

RESPONSE: The content of the CONTROL FIELD of a Response Frame advising the PRIMARY with respect to the processing by the SECONDARY of one or more COMMAND FRAMES.

RESPONSE FRAME: All FRAMES that may be transmitted by a SECONDARY are referred to as RESPONSE FRAMES.

SECONDARY: That portion of a Secondary station responsible for performing LINK LEVEL operations, as instructed by the PRIMARY. A SECONDARY interprets received COMMANDS and generates RESPONSES.

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SECONDARY STATUS: The current condition of a SECONDARY with respect to processing the series of COMMANDS received from the PRIMARY.

UNNUMBERED COMMANDS: The commands that do not contain sequence numbers in the CONTROL FIELD.

UNNUMBERED RESPONSES: The responses that do not contain sequence numbers in the CONTROL FIELD.

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APPENDIX B - ADDITIONAL INFORMATION

This appendix provides additional explanatory information to assist in the use of the standard. For ease of reference, the organization of this appendix is identical to that of the body of the standard.

3.4 Frame Structure, Information Field

Although the maximum length of the information field is theoretically unlimited it will be constrained by one or more of the following factors:

1 Error detection capability of the FCS

2 Channel error characteristics and data rates

3 Station buffer sizes and strategies

4 Logical properties of the data

3.1 Flag Sequence, and 3.8 Time Fill

Although this standard permits the closing flag of one frame to be the opening flag of the next frame, it must be recognized that in certain implementations this may result in crisis time problems. Under those conditions, it may be necessary to transmit interframe time fill. The amount of time fill must be determined by prior agreement.

3.9 IDLE Link State

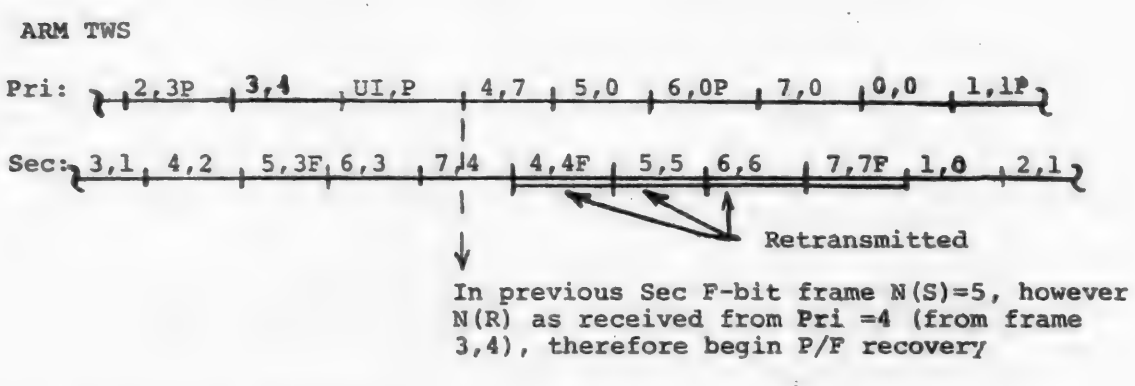
Detection of an IDLE link condition may require the use of a timer or an alternate clock to determine receipt of a continuous one condition for 15 bit times if the link configuration does not provide clock signals in an IDLE condition.

7.4.2.1 Unnumbered Information, UI, Command

A Secondary must respond upon receipt of a UI command frame with the P bit set to "1"; the response shall be any appropriate frame(s), one of which will have the F bit set to "1". A UI command with the P bit set to "0" solicits no response.

8.2 N(S) Sequence Error

In P/F bit recovery if the P or F bit is contained in a U frame, the N(R) number that exists at the receiver when P/F bit recovery is initiated can, under some circumstances, be incorrect. (See example below.) Therefore stations which initiate P/F bit recovery when the P/F bit is in a U frame must be prepared to receive retransmitted frames which have N(S) members that have been previously received and acknowledged. I frames are not lost or duplicated in these instances, however link efficiency is decreased due to the transmission of duplicate I frames.



11.0 Classes of Procedures

There are two forms of point-to-point two-way simultaneous (P-P TWS) operations that are possible using Primary/Secondary configurations. They are:

A. Primary/Secondary ARM TWS
B. Primary/Secondary Back-to-Back ARM or NRM TWS

A. Primary/Secondary Asynchronous Response Mode (ARM) Operation.

Section 11.2 defines Primary-Secondary classes of operation that can be used in such a manner so as to provide a capability similar to Balanced Control (sometimes called "Primary/Primary") in which balanced information transfer in ARM is achieved with Primary function required in only one

station and Secondary function required in the other. See Figure B1. Balanced information transfer is achieved by virtue of symmetrical functional equivalency of the I, RR, RNR, REJ, SREJ and CMDR/RSPR commands and responses. Only the station designated as Primary, however, has the functional use of the mode setting and DISC commands for resetting or disconnecting logical link functions. The capability offered by this type of operation may indeed be satisfactory and optimal for a great many applications envisioned.

The independence of operation at each end of the link with regard to originating information transmission is illustrated in the examples in Section 9.0 of Appendix C for I frame transmission from Primary only, Secondary only, and simultaneous Primary and Secondary.

The two-station configuration in Figure B1 is extendable to a multipoint link configuration; i.e., one Secondary is placed in ARM (and operates point-to-point with the Primary) and all other Secondaries are sent a DISC command. Thus the Primary can perform balanced control type operation with one station at a time.

In case of failure of the TWS link, Primary/Secondary ARM has the ability to substitute a single dial-up line and operate in ARM TWA.

B. Back-to-Back Primary/Secondary Operation

For those cases where completely balanced and independent operation is desirable, the capability exists within the definition of Primary-Secondary operation to accomplish a "Balance Control" arrangement. This can be done in the following manner.

A Primary and Secondary link control function is required in each station with the use of two addresses (and associated sequence numbers) to direct transmissions received to either the Primary or Secondary link control function (see Figure B2). Primary A has use of the full repertoire of commands relative to Secondary B and Secondary B has use of the full repertoire of responses relative to Primary A. The same is also applicable between Primary B and Secondary A. Transmissions from Primary A to Secondary B and transmissions from Secondary A to Primary B are multiplexed

on a frame by frame basis as required in one direction of the TWS facility (i.e., in Figure B1 from right to left). Transmission from Primary B to Secondary A and transmissions from Secondary B to Primary A are similarly multiplexed in the other direction (i.e., in Figure B2 from left to right).

By this means logical interaction between Primary A and Secondary B is independent of the logical interaction between Primary B and Secondary A. There is no procedural restriction that information (data) flow be only from Primary function to Secondary function (i.e., the Secondary function may transmit I/UI frames, see Example 10.1 Appendix C), although this constraint may be accomplished if desirable in several different ways, e.g., at link level by use of RNR to Poll for non-information responses only (See Example 10.2 Appendix C) or by prior system agreement that the Secondary never transmit I/UI frames. (See Example 10.3 Appendix C)

Back-to-Back Primary-Secondary operation offers the flexibility of response in that each sublink (one Primary to one Secondary) may optionally be operated in either ARM or NRM; i.e., one Primary-Secondary pair could be operated in ARM, where the Secondary responds asynchronously, and the other Primary-Secondary pair in NRM, where the Secondary only responds when it receives a command frame with the P bit set to "1". The choice of ARM or NRM is a system option; e.g., depends upon whether it is desired to obtain the most immediate Secondary acknowledgment (by using ARM) or to limit the number of Secondary overhead responses (by setting the P bit to "1" only in every nth frame).

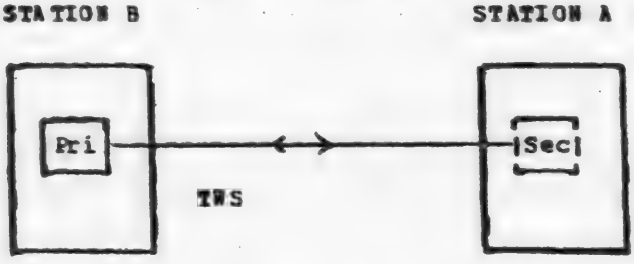


FIGURE B1

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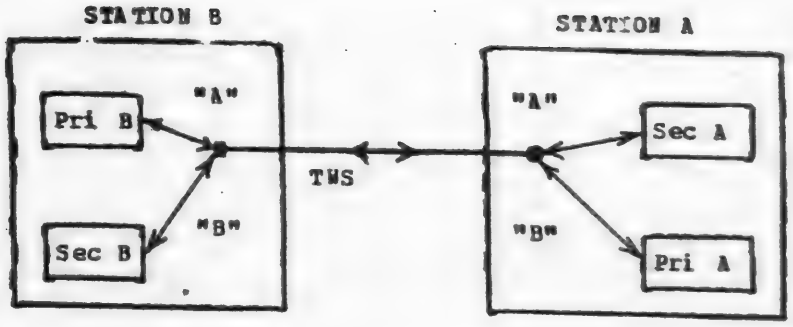

FIGURE B2

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INDEX TO APPENDIX C EXAMPLES

		APPLICABLE CLASSES	TYPE OF RECOVERY ILLUSTRATED
1. NRM TWA EXAMPLES			
1.1 No Errors			
1.1.1	Secondary I Frames only	NB/NS	-
1.1.2	Primary I Frames only	NB/NS	-
1.1.3	Primary and Secondary Frames	NB/NS	-
1.2 Command Frame Errors			
1.2.1	Start-Up	NB/NS	TO
1.2.2	I Frame	NB	P/F
1.2.3	POLL Frame	NB	P/F
1.3 Response Frame Errors			
1.3.1	Start-Up	NB/NS	TO
1.3.2	I Frame	NB	P/F
1.3.3	FINAL Frame	NB	P/F
1.4 Command and Response Frame Errors			
1.4.1	Pri I and Sec FINAL frames	NB	P/F
2. ARM - TWA EXAMPLES			
2.1 No Errors			
2.1.1	Secondary I Frames only	NAB/NAS	-
2.1.2	Contention	NAB/NAS	-
2.2 Command Frame Errors			
2.2.1	Start-Up	NAB/NAS	TO
2.2.2	I Frame	NAB	P/F
2.2.3	POLL Frame	NAB	P/F
2.3 Response Frame Errors			
2.3.1	Start-Up	NAB/NAS	TO
2.3.2	I Frame	NAB	P/F
2.3.3	FINAL Frame	NAB	P/F

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		APPLICABLE CLASSES	TYPE OF RECOVERY ILLUSTRATED
3. NRM - TWS EXAMPLES			
3.1 No Errors			
3.1.1	Secondary I Frames only	NB/NS	-
3.1.2	Primary I Frames only	NB/NS	-
3.1.3	Secondary and Primary I Frames	NB/NS	-
3.2 Command Frame Errors			
3.2.1	I Frame	NB	REJ
3.2.2	I Frame	NS	SREJ
3.3 Response Frame Errors			
3.3.1	I Frame	NB	REJ
3.3.2	I Frame	NS	SREJ
4. ARM - TWS EXAMPLES			
4.1 No Errors			
4.1.1	Intermittent I Frames From Pri & Sec	NAB/NAS	-
4.1.2	Continuous I Frames From Pri & Sec	NAB/NAS	-
4.2 Command Frame Errors			
4.2.1	Start-Up	NAB/NAS	TO
4.2.2	I Frame	NAB	REJ
4.2.3	I Frame	NAS	SREJ
4.2.4	I Frame	NAB	P/F
4.3 Response Frame Errors			
4.3.1	I Frame	NAB	REJ
4.3.2	I Frame	NAS	SREJ
4.3.3	I Frame	NAB	P/F

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5. MODE CHANGING EXAMPLES

5.1 NRM to ARM - TWA Examples

5.1.1	Orderly Change, Pri & Sec I Frames	NAB/NAS	-
5.1.2	Orderly Change, Pri Only I Frames	NAB/NAS	-
5.1.3	Orderly Change, Sec Only I Frames	NAB/NAS	-

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		APPLICABLE CLASSES	TYPE OF RECOVERY ILLUSTRATED
5.2 NRM to ARM - TWS Examples			
5.2.1	Immediate Change, Pri & Sec I Frames	NAB/NAS	-
5.2.2	Orderly Change, Pri Only I Frames	NAB/NAS	-
5.2.3	Orderly Change, Sec Only I Frames	NAB/NAS	-
5.3 ARM to NRM - TWA Examples			
5.3.1	Orderly Change, Pri & Sec I Frames	NAB/NAS	-
5.3.2	Orderly Change, Pri Only I Frames	NAB/NAS	-
5.3.3	Orderly Change, Sec Only I Frames	NAB/NAS	-
5.4 ARM to NRM - TWS Examples			
5.4.1	Immediate Change, Pri & Sec I Frames	NAB/NAS	
5.4.2	Orderly Change, Pri Only I Frames	NAB/NAS	-
5.4.3	Immediate Change, Sec Only I Frames	NAB/NAS	-
5.5 NDM/ADM Examples			
5.5.1	NDM/ADM to APM - TWA	NAB/NAS	-
5.5.2	NDM/ADM to NRM - TWA	NAB/NAS	-
5.5.3	NDM/ADM TWA, Pri Actions Sec Request	NAB/NAS	-
5.5.4	NDM/ADM TWA, Pri Refuses Sec Request	NAB/NAS	-
6. CLOSING PROCEDURE EXAMPLES			
6.1 NRM - TWA		NB/NS	-
6.2 NRM - TWS		NB/NS	
6.3 ARM - TWA		NAB/NAS	
6.4 ARM - TWS		NAB/NAS	

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	APPLICABLE CLASSES	TYPE OF RECOVERY ILLUSTRATED
7. EXCEPTION RECOVERY - TWS EXAMPLES		
7.1 REJ + P/F Bit Exception Recovery		
7.1.1 NRM, SEC Receives REJ	NB	REJ
7.1.2 NRM, SEC Misses REJ	NB	P/F
7.1.3 ARM, SEC Receives REJ	NAB	REJ
7.1.4 ARM, SEC Misses REJ	NAB	P/F
7.2 SREJ & REJ Exception Recovery		
7.2.1 NRM TWS, Pri Receives	NS	SREJ
7.2.2 NRM TWS, Pri Misses SREJ	NS	Errored SREJ
7.2.3 ARM TWS, Pri Receives SREJ	NAS	SREJ
7.2.4 ARM TWS, Pri Misses SREJ	NAS	Errored SREJ
7.2 SREJ + REJ Exception Recovery		
7.2.1 NRM, Pri Receives SREJ	NS	SREJ
7.2.2 NRM TWS, Pri Misses SREJ	NS	Errored SREJ
7.2.3 ARM TWS, Pri Receives SREJ	NAS	SREJ
7.2.4 ARM TWS, Pri Misses SREJ	NAS	Errored SREJ
8. BALANCED CONTROL OPERATION EXAMPLES		
8.1 Continuous I Frames	BCB/BCS	-
8.2 Intermittent I Frames	BCB/BCS	-
9. ARM TWS POINT-TO-POINT		
9.1 Continuous Pri & Sec I Frames	NAB/NAS	-
9.2 Continuous Pri & Intermittent Sec I Frames	NAB/NAS	-
9.3 Intermittent Pri & Continuous Sed I Frames	NAB/NAS	-
10. DOUBLE PRIMARY & SECONDARY ARM TWS POINT-TO-POINT EXAMPLES (Called BACK-TO-BACK)		
10.1 Start-UP/Continuous Pri & Sec I Frames	NAB/NAS	-

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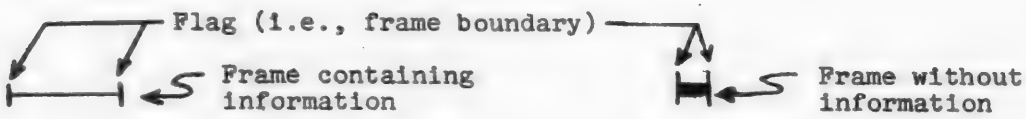
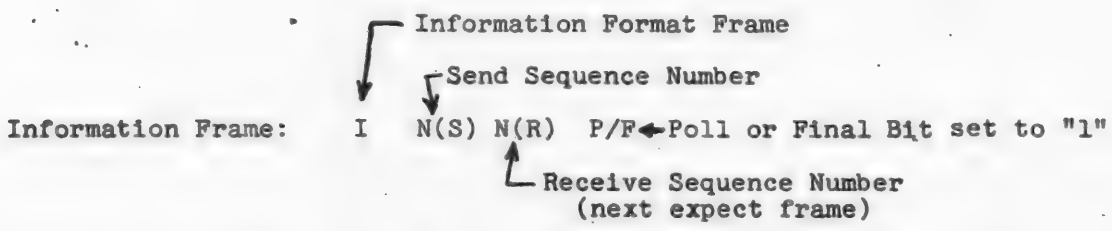
10.2 Start-Up Continuous Pri Only I Frames (via RNR)	NAB/NAS	-
10.3 Start-UP/Continuous Pri Only I Frames (prior agreement)	NAB/NAS	-

APPENDIX C: EXAMPLES OF THE USE OF COMMANDS AND RESPONSES

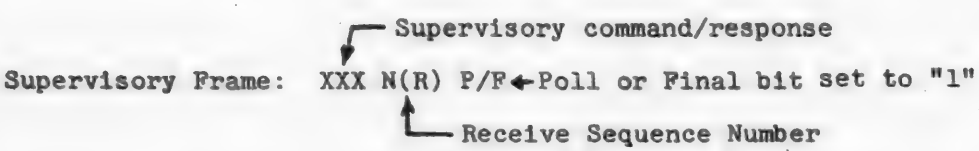
The examples in Appendix C are offered for illustrativ purposes only and should not be interpreted as establishing any protocol; the exchange of the various command and response frames is limited only by the rules specified in the standard.

The notation used in the Appendix C diagrams is illustrated below:

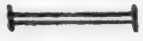



Information Format Frame
Send Sequence Number
Information Frame: I N(S) N(R) P/F
Poll or Final Bit set to "1"
Receive Sequence Number (next expect frame)

Example: Pri xmits: I2,6P. This denotes a Primary Information format frame with sequence number 2, the next expected frame from the Secondary is sequence number 6 (frames numbered 5 and below are therefore acknowledged) and the Poll bit is set to "1" (i.e., the Secondary is to initiate transmission with Information format frames if available).



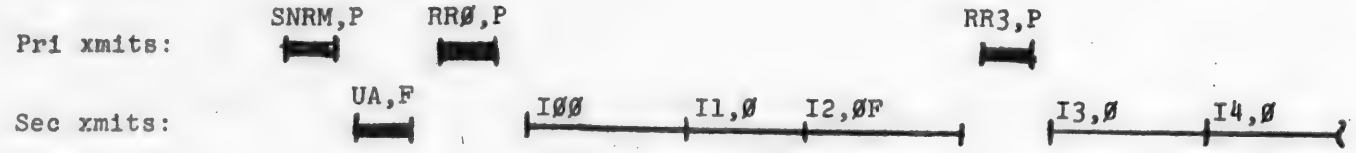
Example: Pri xmits: RR2P. This denotes a Receive Ready (RR) command, N(R)=2 (i.e., the next expected frame from the Secondary is sequence number 2), and the Poll bit is set to "1".

NOTE: Retransmitted Information format frames are shown with a double line; i.e.,  .

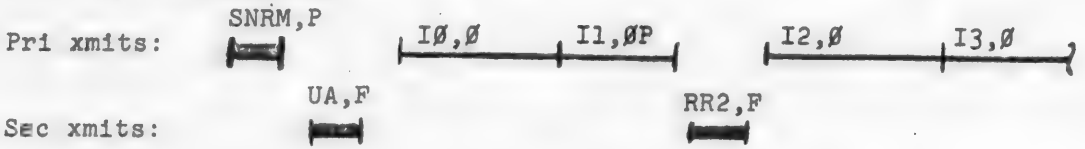
1. Examples of Normal Response Mode (NRM) 2 Way Alternate (TWA) Transmission

1.1 **NRM TWA Without Transmission Errors**

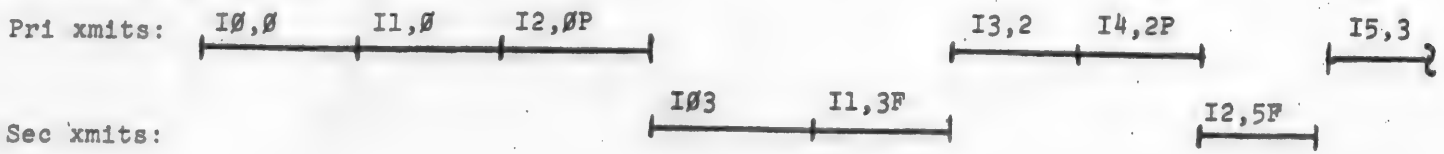
1.1.1 NRM Start-up procedure and Secondary only information transfer (NB/NS CLASSES)



1.1.2 NRM Start-up procedure and Primary only information transfer (NB/NS CLASSES)

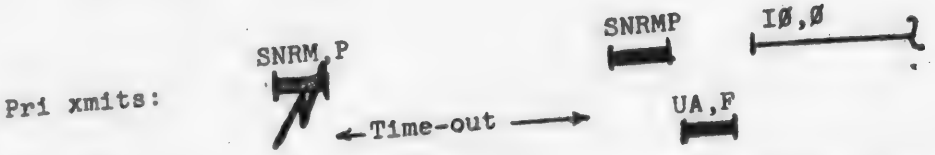


1.1.3 NRM information transfer by Primary and Secondary (NB/NS CLASSES)

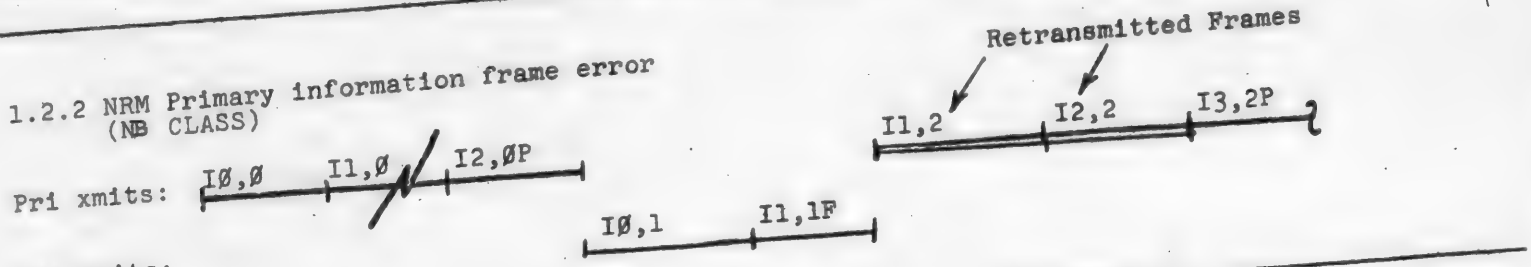


1.2 NRM TWA with transmission errors in command frames

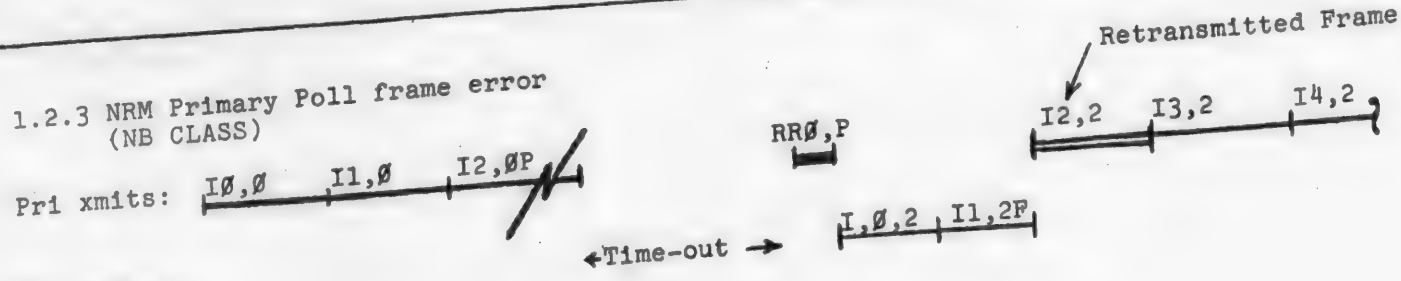
1.2.1 NRM Start-up command error (NB/NS CLASSES)



1.2.2 NRM Primary information frame error (NB CLASS)

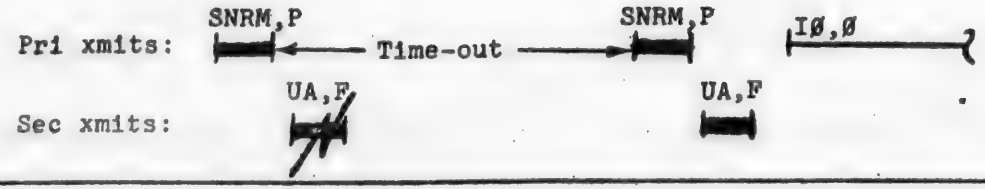


1.2.3 NRM Primary Poll frame error (NB CLASS)

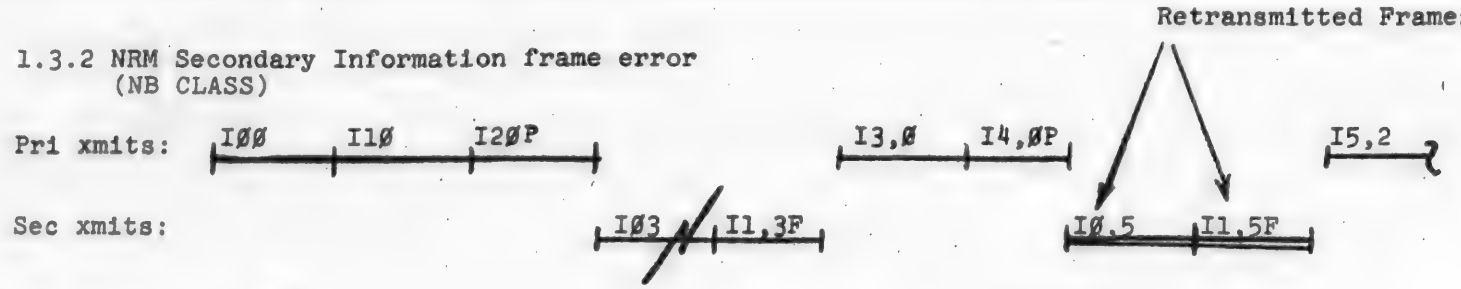


1.3 NRM TWA with transmission errors in response frames

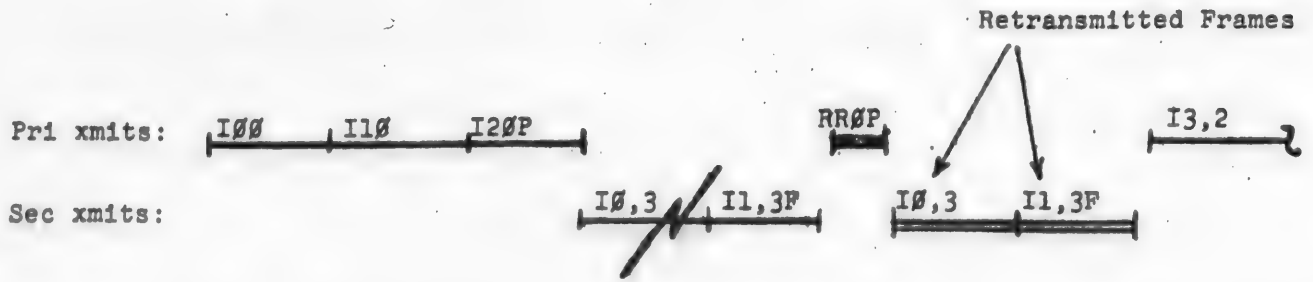
1.3.1 NRM Start-up response error
(NB/NS CLASSES)



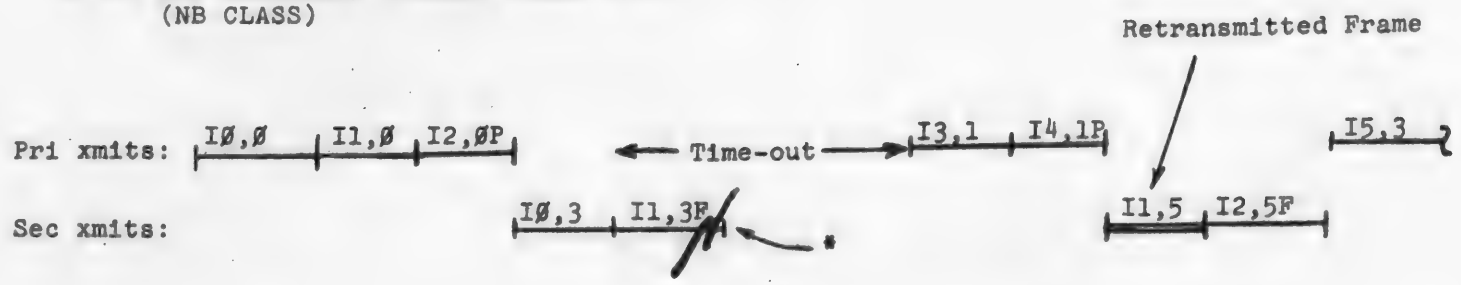
1.3.2 NRM Secondary Information frame error
(NB CLASS)



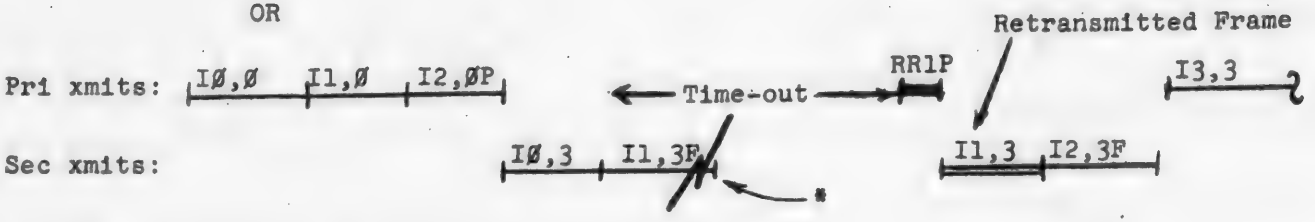
OR



1.3.3 NRM Secondary "Final" frame error
(NB CLASS)

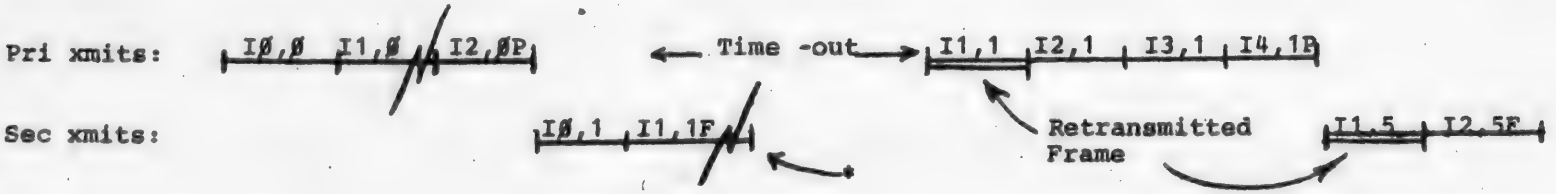


OR



1.4 NRM TWA Command and Response Frame Errors

1.4.1 NRM TWA Primary I and Secondary "Final" I Frame Errors
(NB/NAB CLASSES)

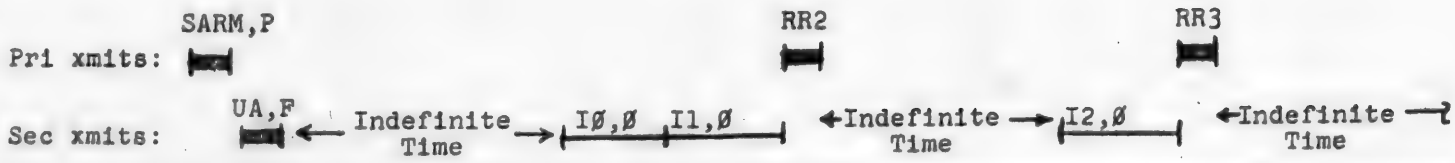


* Idle Link State detection may be used in place of Time-out to initiate Primary Transmission.

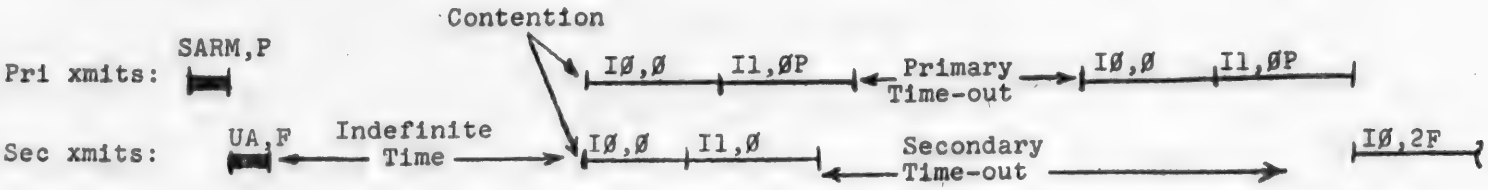
2. Examples of Asynchronous Response Mode (ARM) 2-Way Alternate (TWA) Transmission

2.1 ARM TWA Without Transmission Error

2.1.1 ARM Start-up procedure and Secondary only information transfer

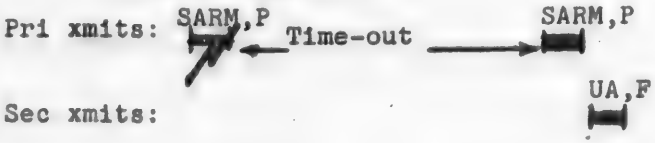


2.1.2 ARM Primary and Secondary information transfer with contention situation (NAB/CLASS)



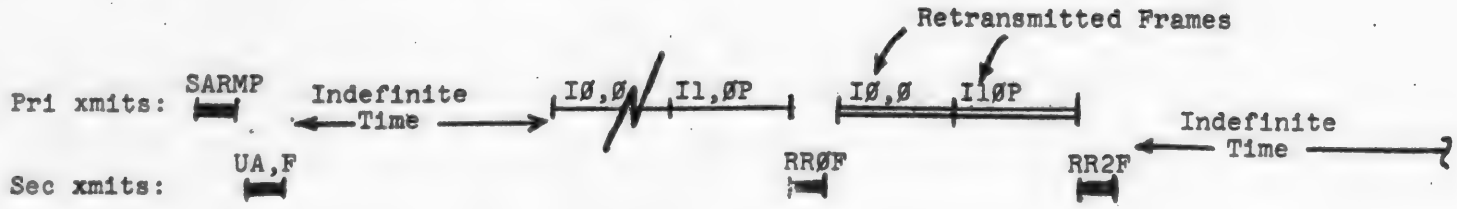
2.2 ARM TWA With Transmission Errors in Command Frames

2.2.1 ARM Start-up command error (NAB/NAS CLASSES)

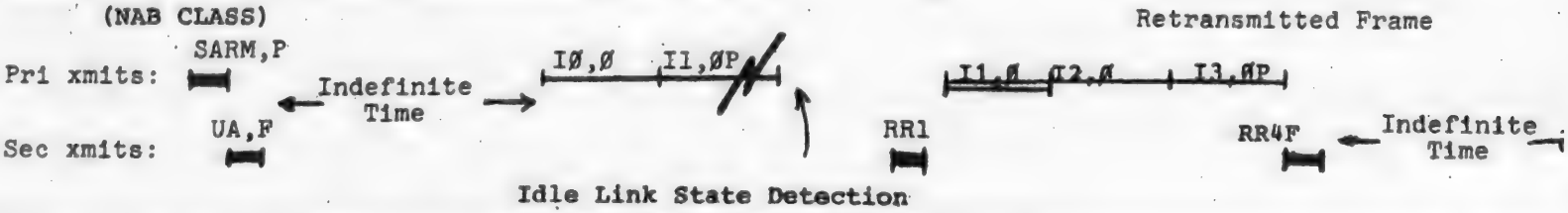


NOTE: All turnarounds in ARM TWA are by means of Idle Link State detection.

2.2.2 ARM Primary information frame error
(NAB CLASS)

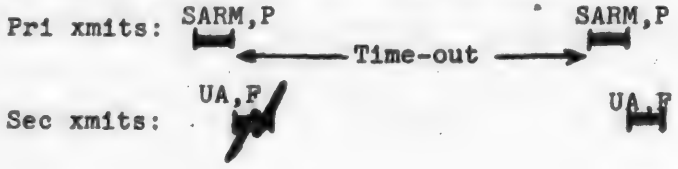


2.2.3 ARM Primary "Poll" information frame error
(NAB CLASS)

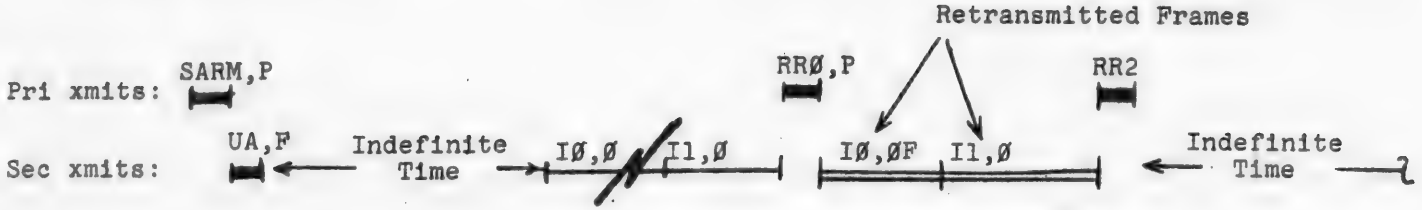


2.3 ARM TWA With Transmission Errors in Response Frames

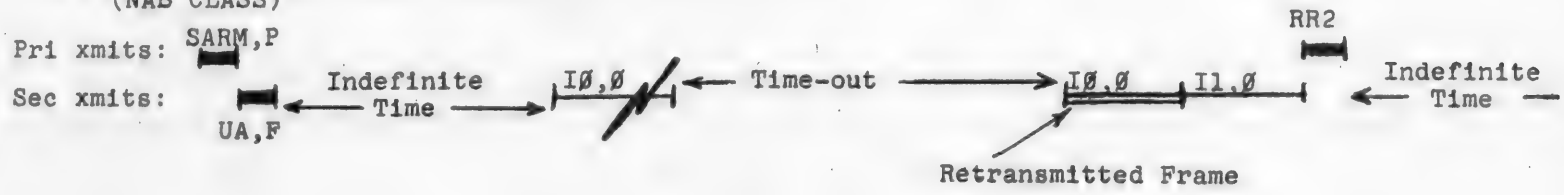
2.3.1 ARM Start-up (NAB/NAS CLASSES)



2.3.2 ARM Secondary information frame error
(NAB CLASS)



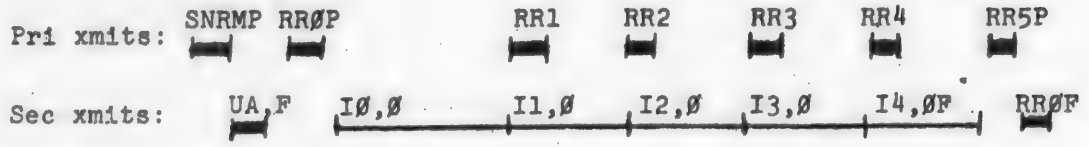
2.3.3 ARM Secondary "Final" information frame error
(NAB CLASS)



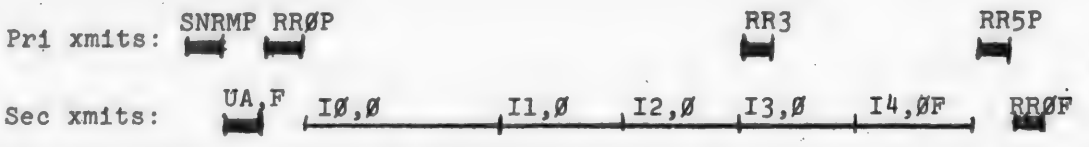
3. Examples of Normal Response Mode (NRM) 2-Way Simultaneous (TWS) Transmission

3.1 NRM TWS Without Transmission Errors

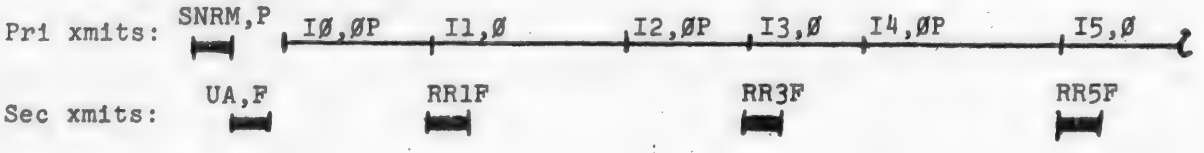
3.1.1 NRM Start-up procedure and Secondary only information transfer (NB/NS CLASSES)



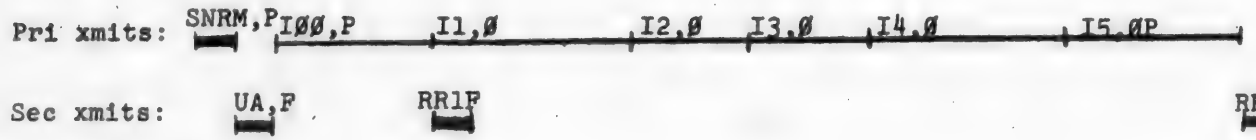
OR (where Primary acknowledgements are returned for several response frames)



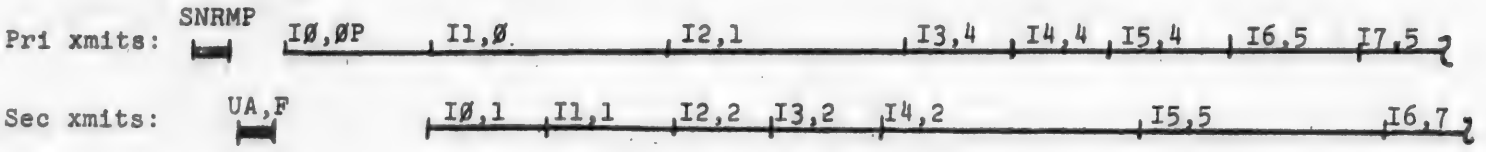
3.1.2 NRM Start-up procedure and Primary only information transfer (NB/NS CLASSES)



OR (where Primary sets Poll bit to "1" to solicit acknowledgement for several frames)

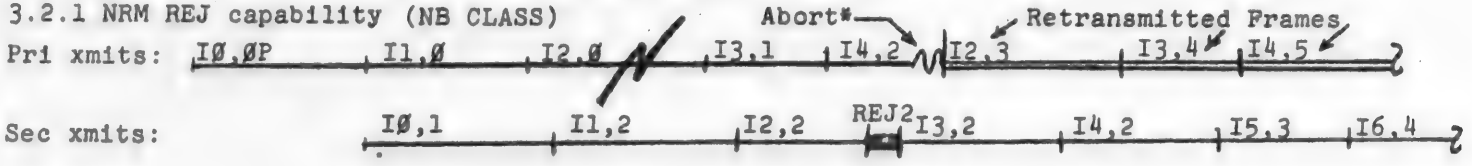


3.1.3 NRM Start-up procedure and Primary/Secondary information transfer (NB/NS CLASSES)



3.2 NRM TWS With Transmission Errors in Command Frames

3.2.1 NRM REJ capability (NB CLASS)



* Optional: Frame maybe completed or aborted

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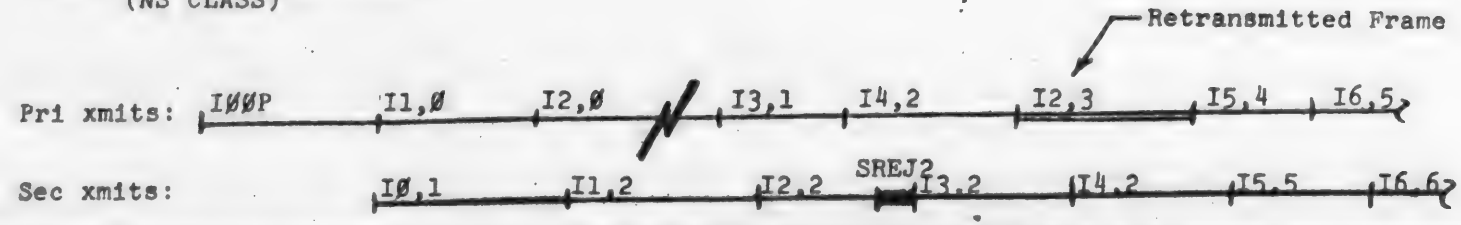
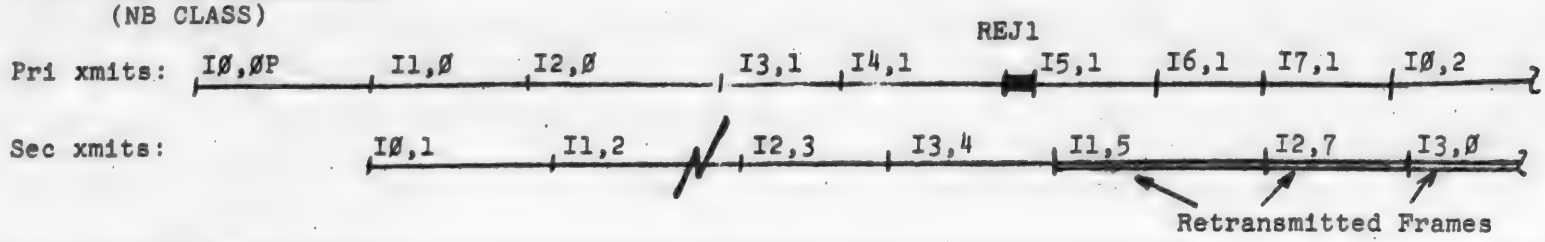
3.2.2 NRM SREJ capability
(NS CLASS)

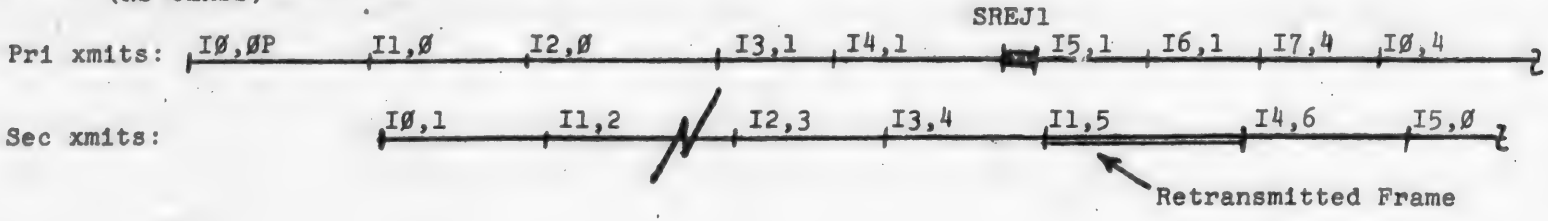


3.3 NRM TWS With Transmission Errors in Response Frames

3.3.1 NRM REJ capability
(NB CLASS)



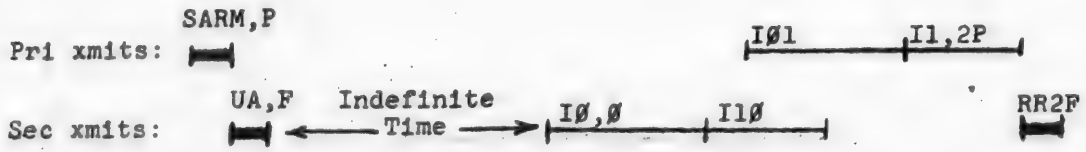
3.3.2 NRM SREJ capability
(NS CLASS)



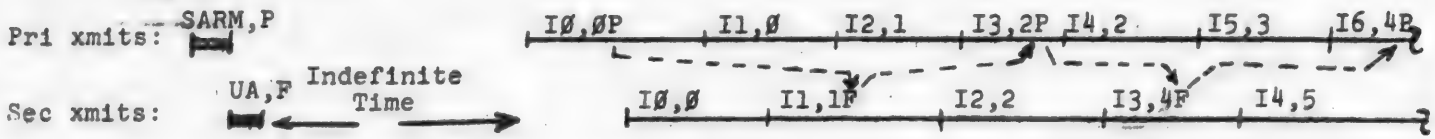
4. Examples of Asynchronous Response Mode (ARM) 2-Way Simultaneous (TWS) Transmission

4.1 ARM TWS Without Transmission Errors

4.1.1 ARM Start-up procedure and intermittent Secondary or Primary information transfer (NAB/NAS CLASSES)

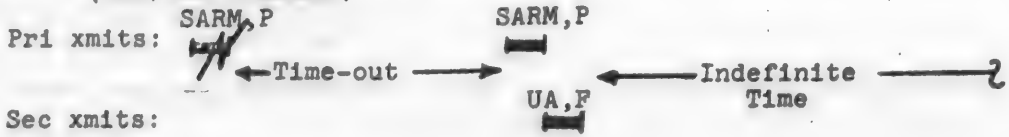


4.1.2 ARM Start-up procedure and continuous Primary Secondary information transfer (NAB/NAS CLASSES)



4.2 ARM TWS With Transmission Errors in Command Frames

4.2.1 ARM Start-up command error (NAB/NAS CLASSES)



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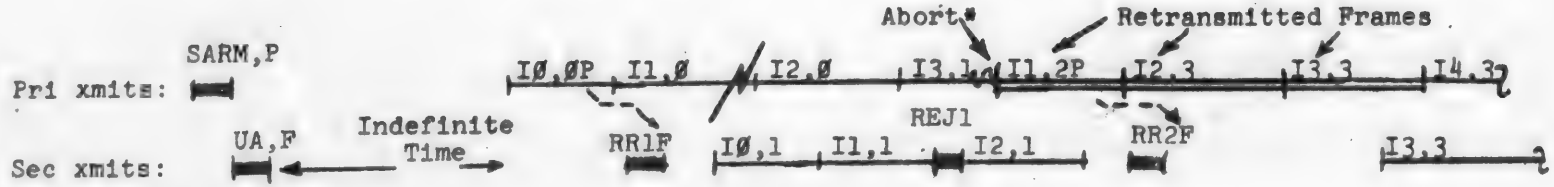
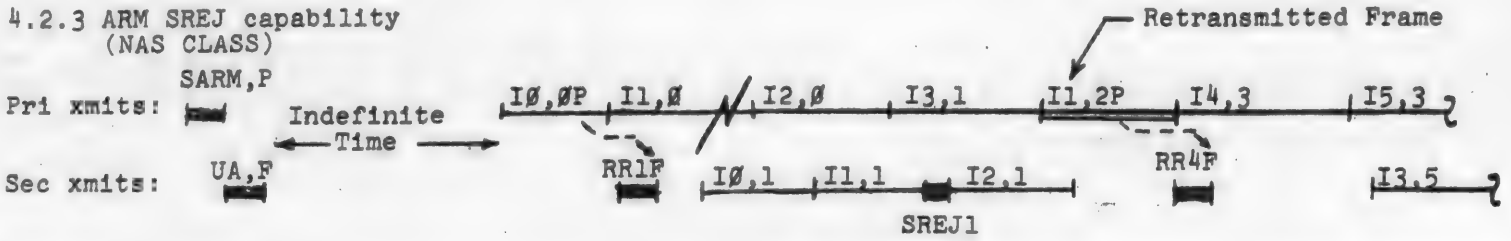
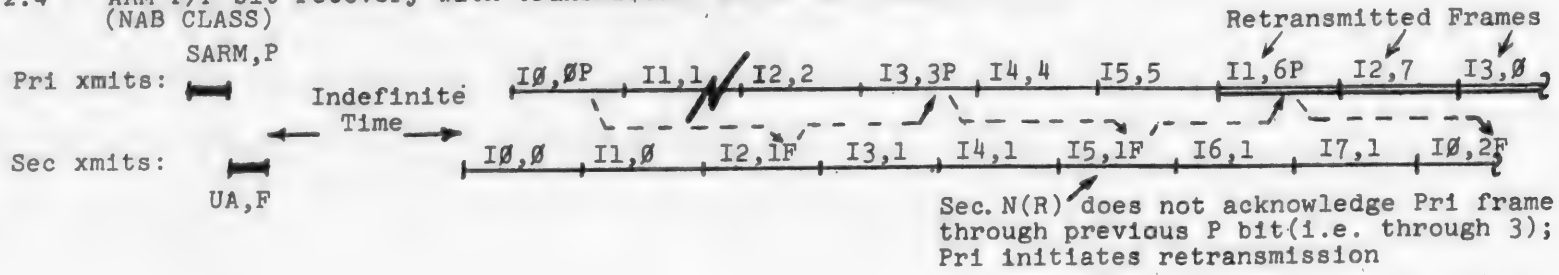
4.2.2 ARM REJ capability
(NAB CLASS)



4.2.3 ARM SREJ capability
(NAS CLASS)



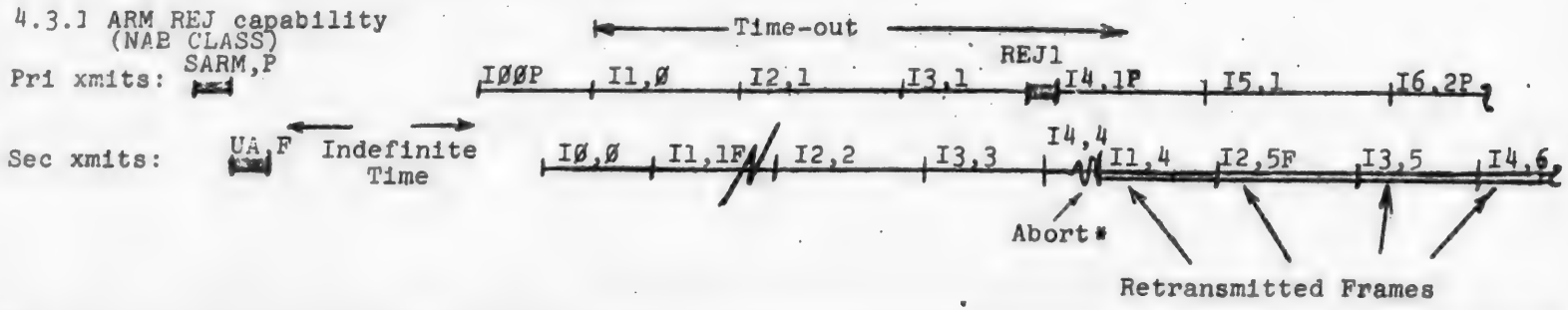
4.2.4 ARM P/F bit recovery with transmission error in command frame
(NAB CLASS)



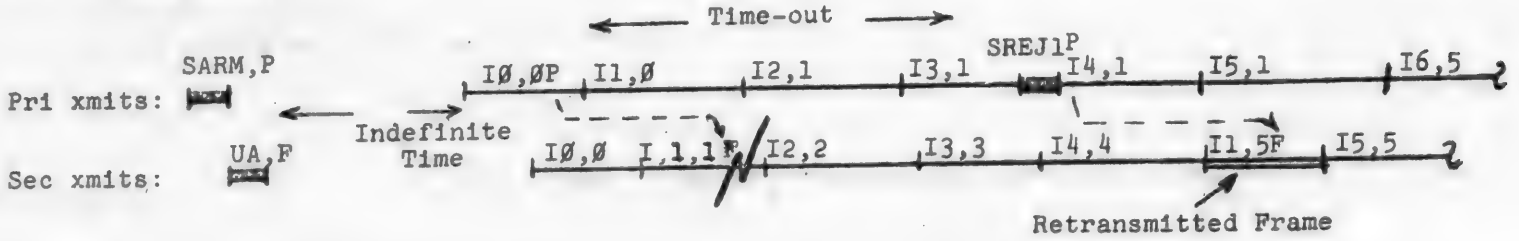
* Optional: Frame may be completed or aborted

4.3 ARM TWS With Transmission Errors In Response Frames

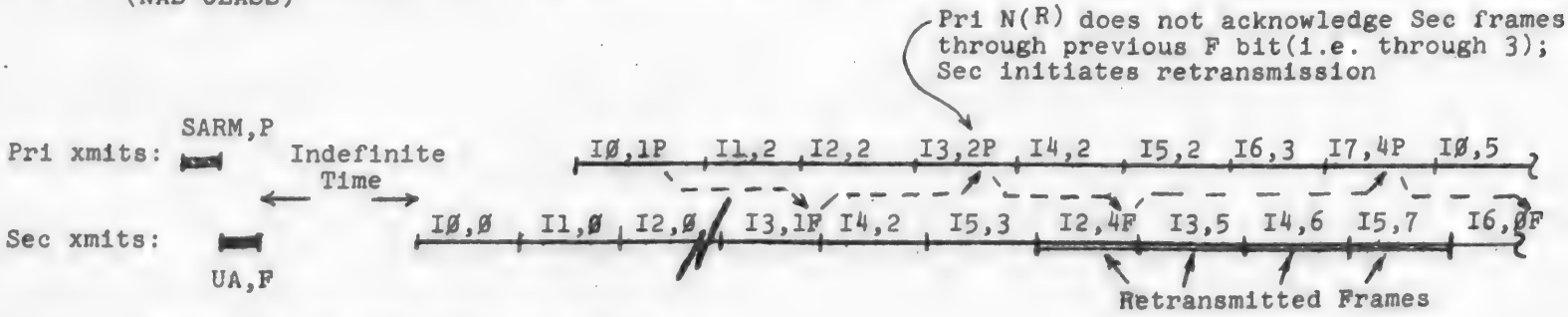
4.3.1 ARM REJ capability
(NAB CLASS)



4.3.2 ARM SREJ capability
(NAS CLASS)



4.3.3 ARM P/F bit recovery with transmission error in response frame
(NAB CLASS)

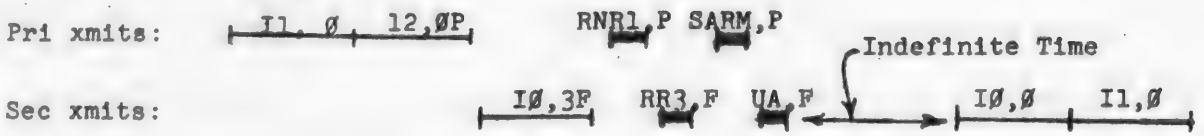


*Optional: Frame may be completed or aborted.

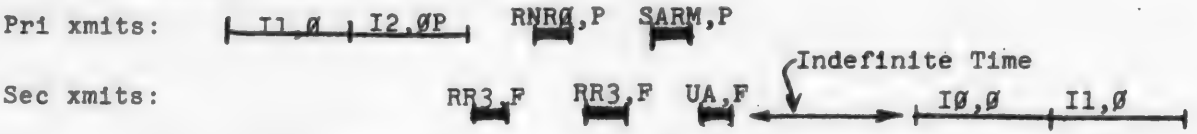
5.0 Examples of Changing Control Mode

5.1 **NRM to ARM 2-Way Alternate (TWA)**

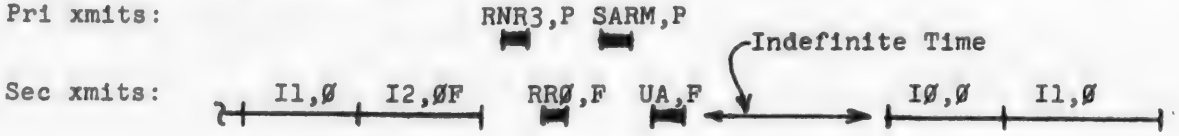
5.1.1 **TWA NRM to ARM Mode Change**
(NAB/NAS CLASSES)



5.1.2 **NRM to ARM Mode Change TWA**
(NAB/NAS CLASSES)

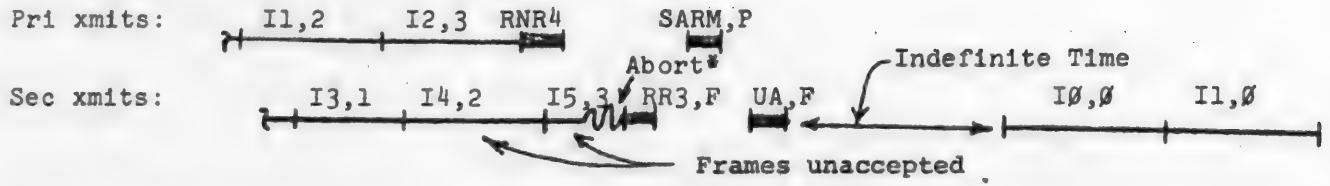


5.1.3 **NRM to ARM Mode Change TWA**
(NAB/NAS CLASSES)

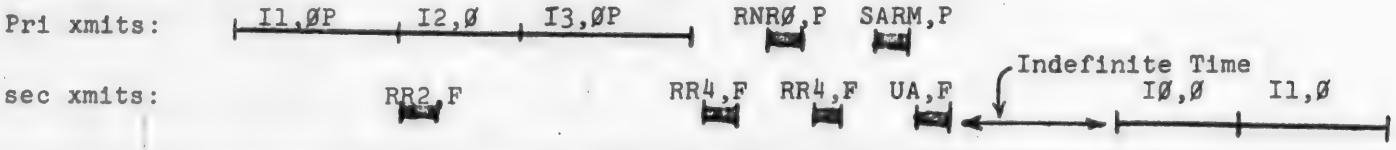


5.2 **NRM to ARM 2-Way Simultaneous (TWS)**

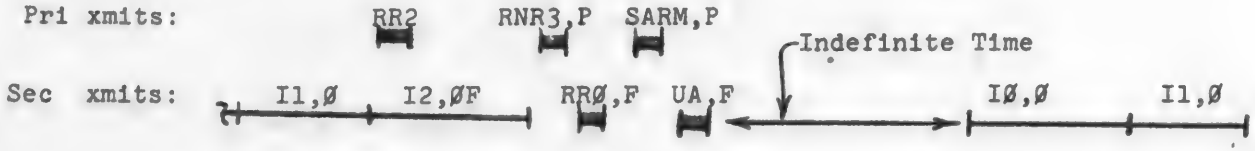
5.2.1 **NRM to ARM Mode Change TWS (Immediate Change)**
(NAB/NAS CLASSES)



5.2.2 **NRM to ARM Mode Change TWS (Orderly Change while Pri xmits)**
(NAB/NAS CLASSES)



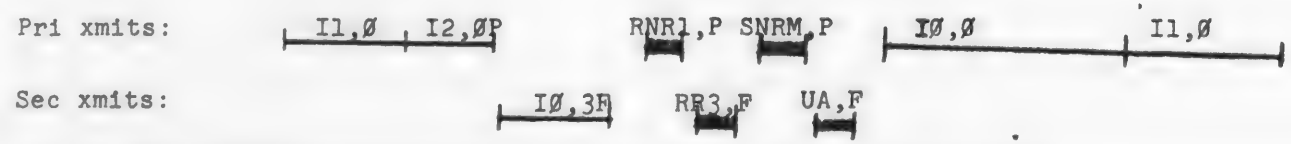
5.2.3 **NRM to ARM Mode Change TWS (Orderly change while Sec xmits)**
(NAB/NAS CLASSES)



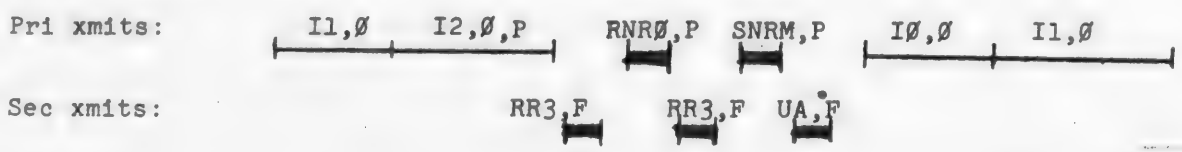
* Optional: Frame may be completed or aborted

5.3 **2-Way Alternate (TWA) ARM to NRM Change**

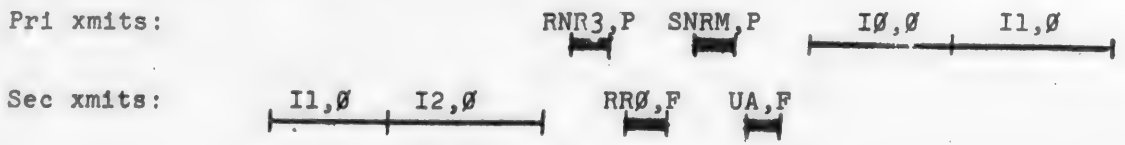
5.3.1 **TWA ARM to NRM Mode Change**
(NAB/NAS CLASSES)



5.3.2 **TWA ARM to NRM Mode Change**
(NAB/NAS CLASSES)

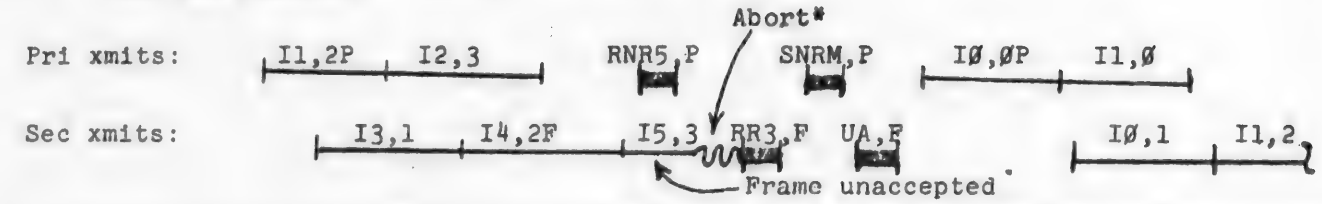


5.3.3 **TWA ARM to NRM Mode Change**
(NAB/NAS CLASSES)

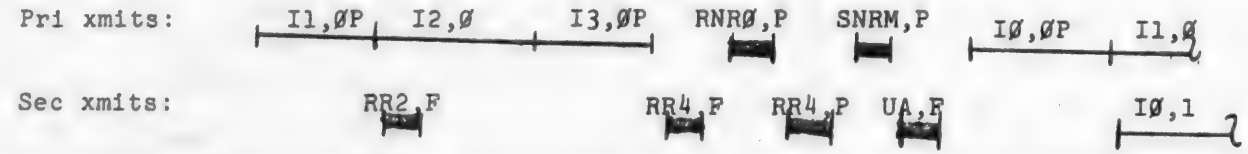


5.4 2-Way Simultaneous (TWS) ARM to NRM Change

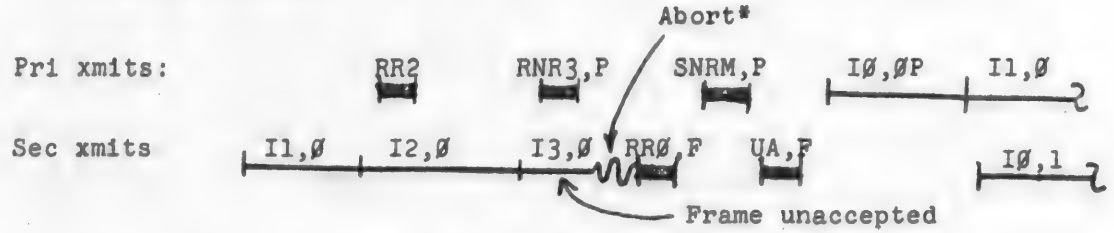
5.4.1 TWS ARM to NRM Mode Change (Immediate Change) (NAB/NAS CLASSES)



5.4.2 TWS ARM to NRM Mode Change (Orderly Change while Pri xmits) (NAB/NAS CLASSES)



5.4.3 TWS ARM to NRM Mode Change (Orderly change while Sec xmits) (NAB/NAS CLASSES)



*Optional: Frame may be completed or aborted.

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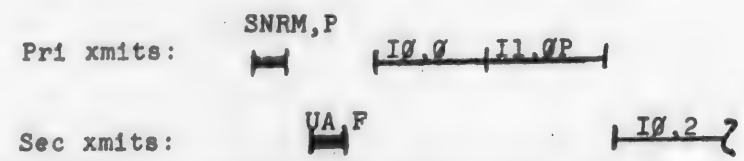
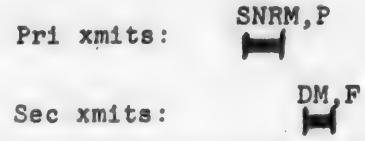
5.5 Normal Disconnected Mode (NDM) Examples

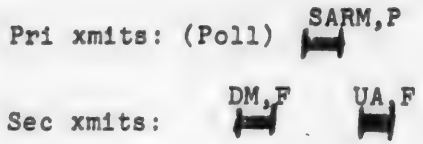
5.5.1 TWA NDM (or ADM) to ARM Change
(NAB/NAS CLASSES)



5.5.2 TWA Secondary in NDM (or ADM) to NRM Change
(Sec. indicates it is unable to change to NRM)
(NAB/NAS CLASSES)

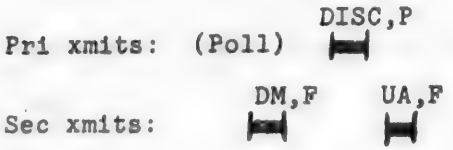


5.5.3 TWA Secondary in ADM
(Sec. indicates it is disconnected and Primary sends set mode command)
(NAB/NAS CLASSES)



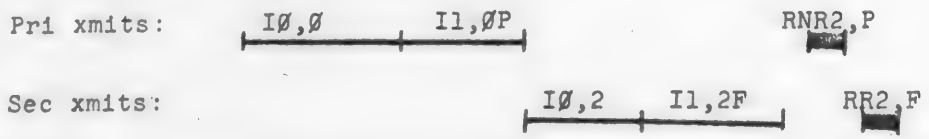
5.5.4 TWA Secondary in NDM (or ADM)
(Sec indicates it is disconnected, and Primary refuses to send set mode command)

(NAB/NAS CLASSES)

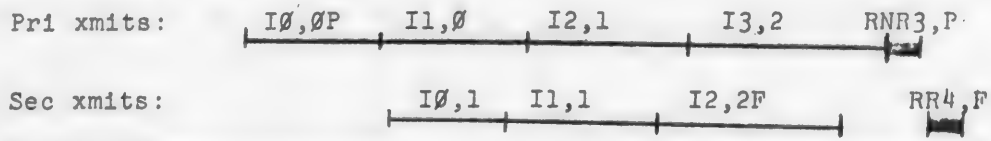


6.0 Examples of End of Operation (General Closing Procedure)

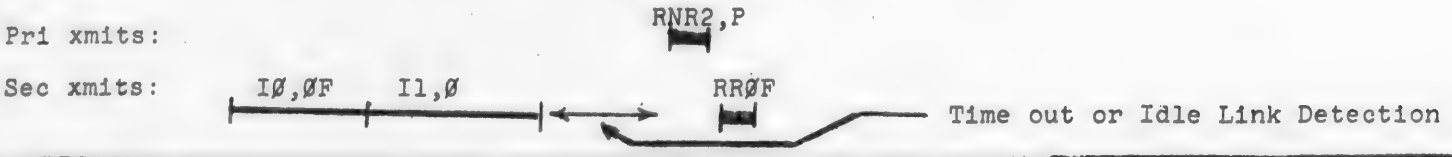
6.1 NRM TWA
(NB/NS CLASSES)



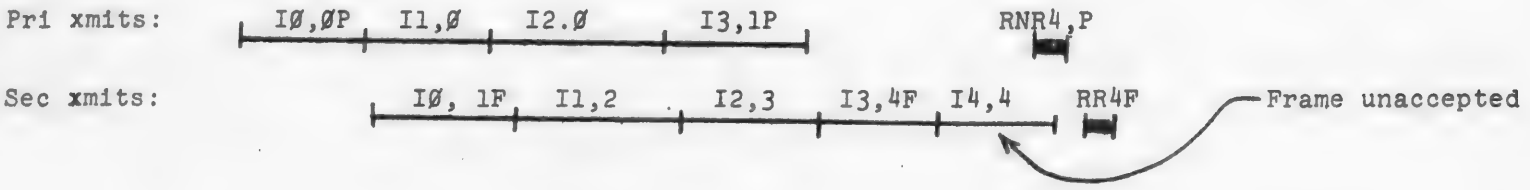
6.2 NRM TWS
(NB/NS CLASSES)



6.3 ARM TWA
NAB/NAS CLASSES)



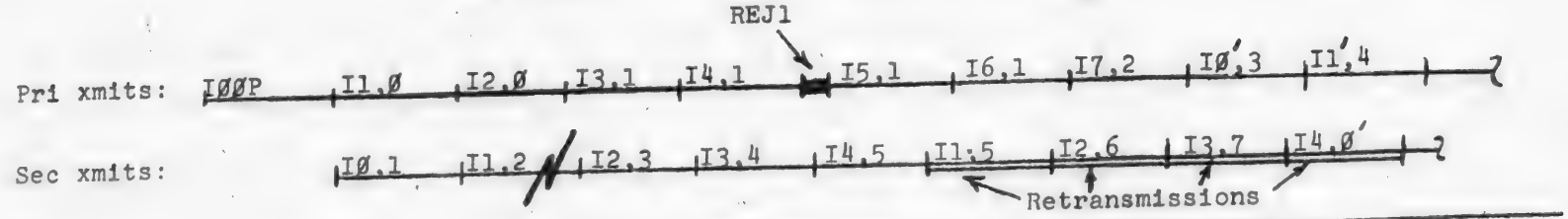
6.4 ARM TWS
(NAB/NAS CLASSES)



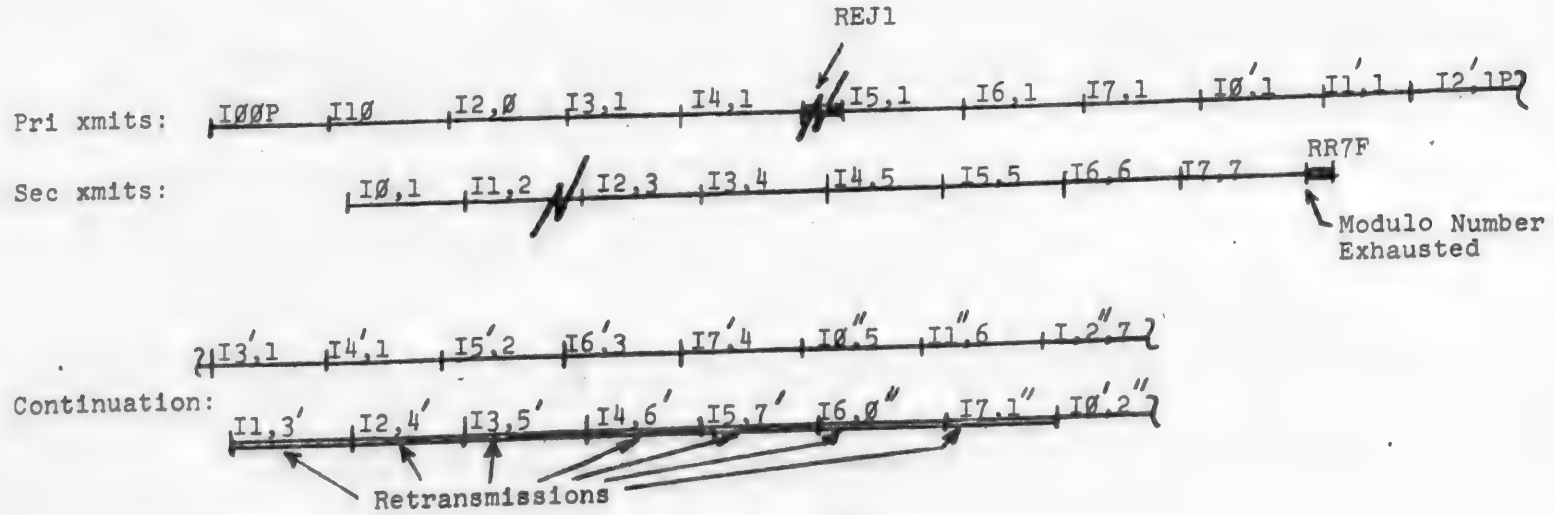
7. Examples of Exception Recovery Procedures

7.1 REJ and Poll/Final Bit Exception Recovery for FDX Operation

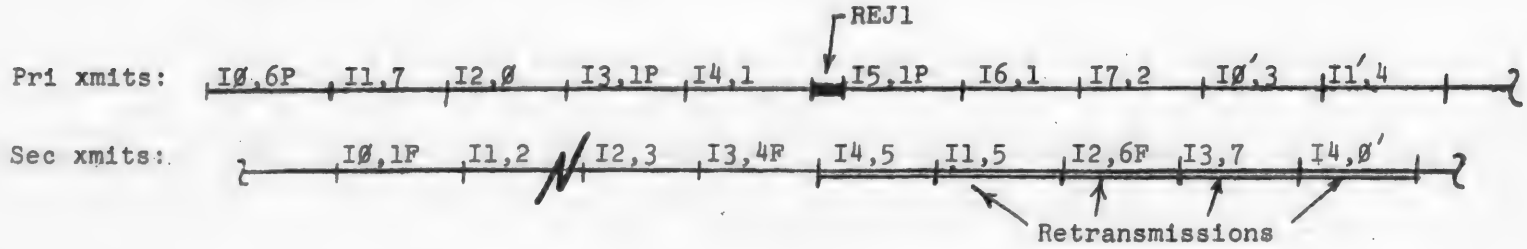
7.1.1 NRM - TWS with Information Frame Exception
(NB CLASS)



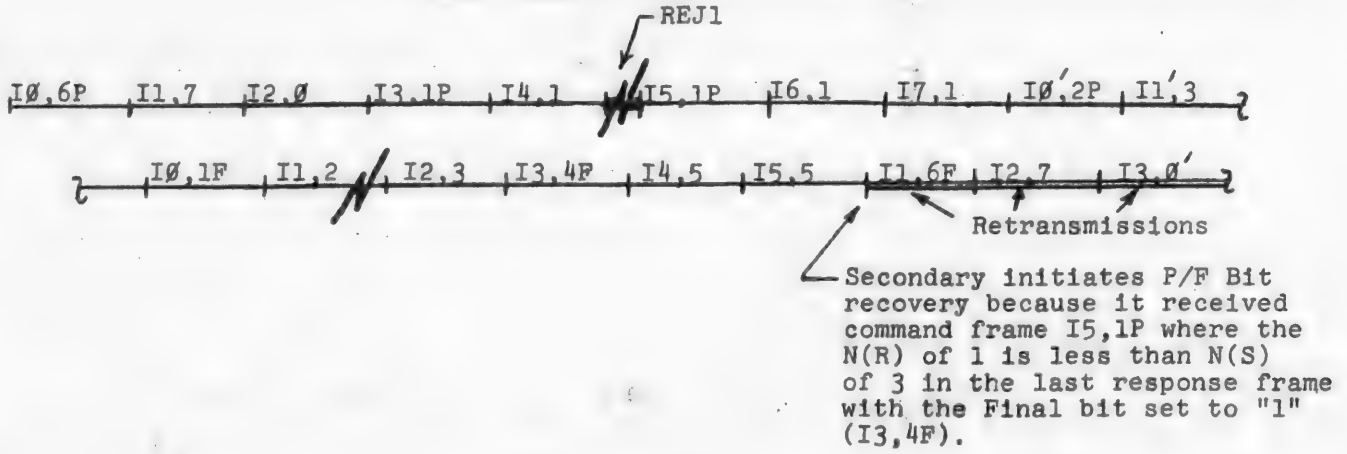
7.1.2 Example 7.1.1 above except REJ is not received correctly.
(NB CLASS)



7.1.3 ARM - TWS with Information Frame Exception
(NAB CLASS)

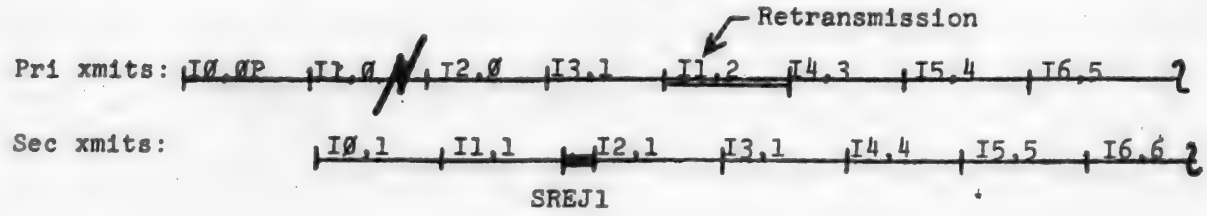


7.1.4 Example 7.1.3 above except REJ is not received correctly
(NAB CLASS)

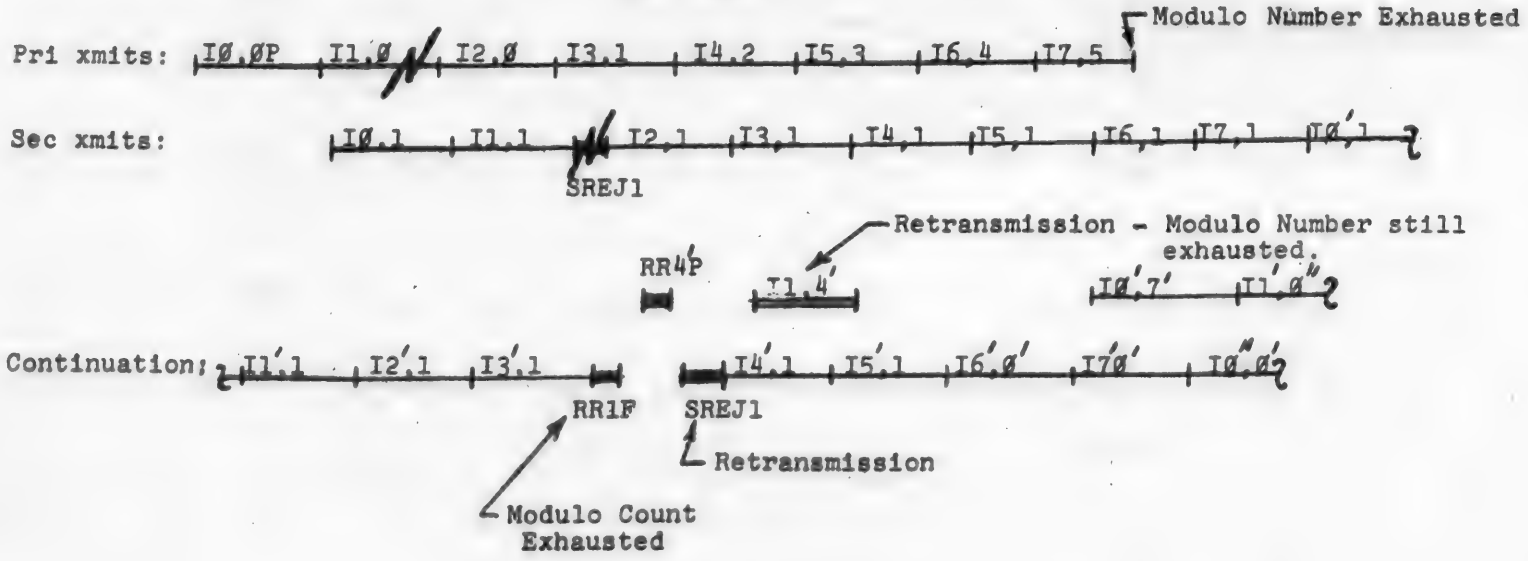


7.2 SREJ/REJ Exception Recovery for FDX Operation

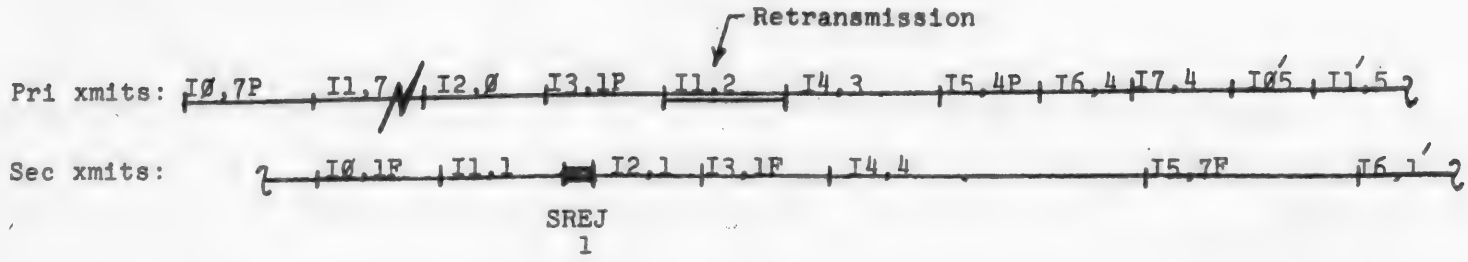
7.2.1 NRM - TWS with Information Frame Exception (NS CLASS)



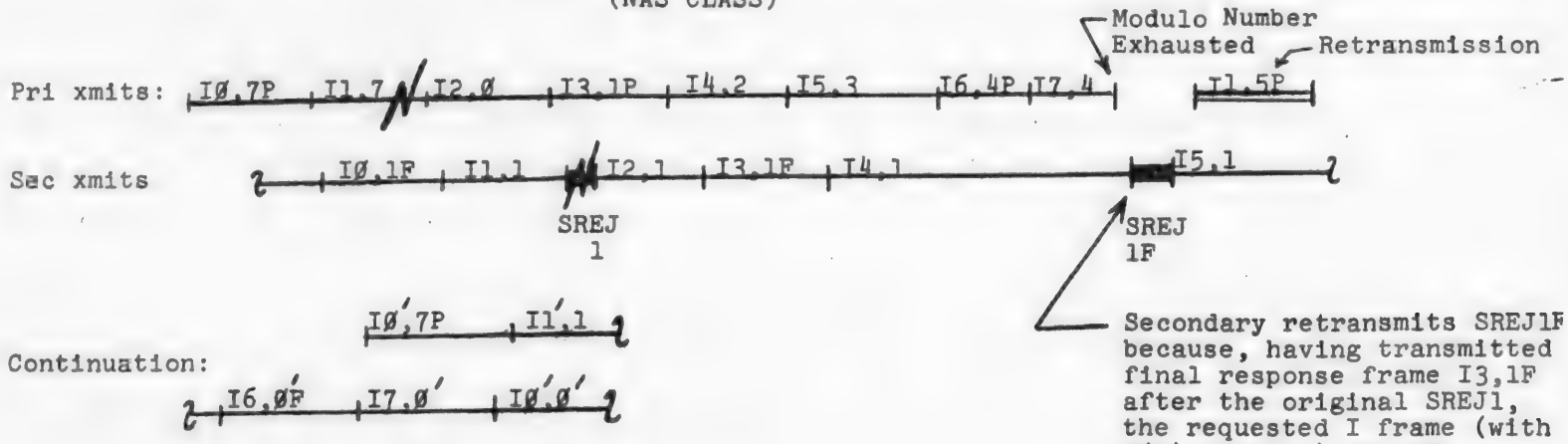
7.2.2 Example 7.2.1 above except SREJ is not received correctly (NS CLASS)



7.2.3 ARM - TWS with I Frame Exception Condition (NAS CLASS)

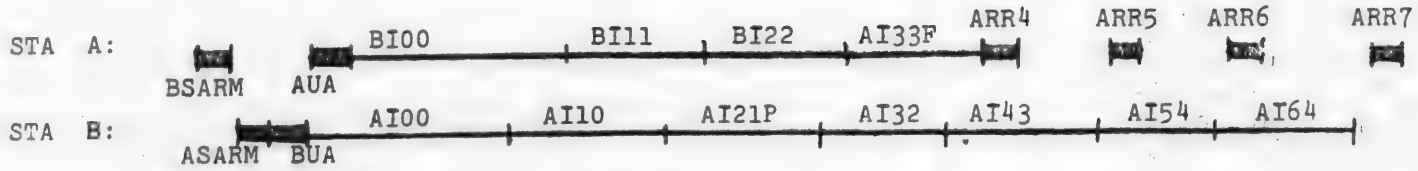


7.2.4 Example 7.2.3 above except SREJ is received in error (NAS CLASS)

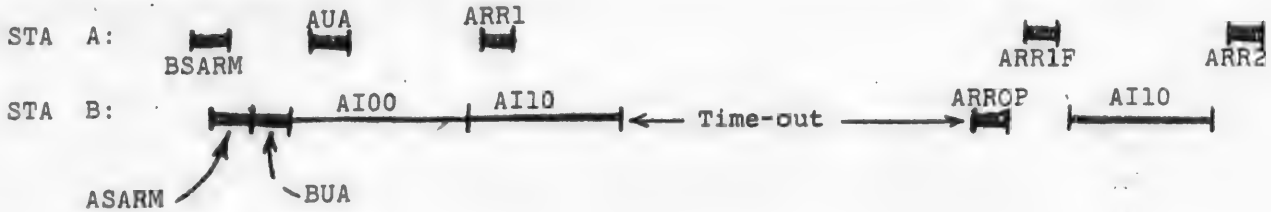

Modulo Number Exhausted
Retransmission
Pri xmits: IØ,7P I1,7 I2,Ø I3,1P I4,2 I5,3 I6,4P I7,4 I1,5P
Sec xmits IØ,1F I1,1 I2,1 I3,1F I4,1 I5,1
SREJ 1
SREJ 1F
Continuation:
IØ',7P I1',1
I6,ØF I7,Ø' IØ',Ø'
Secondary retransmits SREJ1F because, having transmitted final response frame I3,1F after the original SREJ1, the requested I frame (with N(S) equal 1) was not received prior to or concurrent with the next poll command frame I6,4P.

8.0 Examples of Balanced Control Operation

8.1 Continuous Information Frames
(BCB/BCS CLASSES)

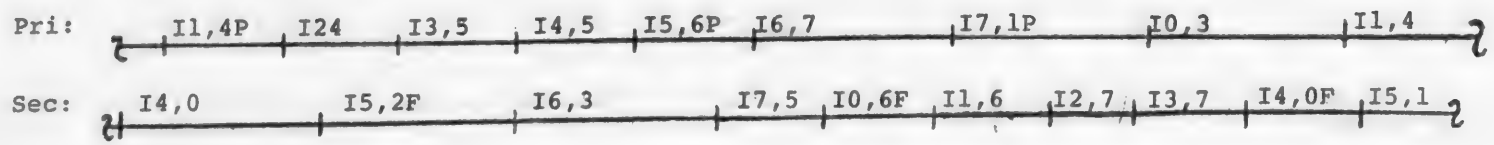


8.2 Discontinuous Information Frames
(BCB/BCS CLASSES)

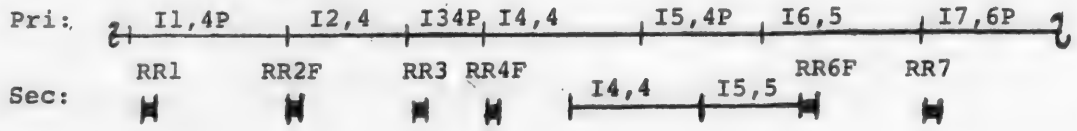


9.0 Primary-Secondary ARM Two-Way Simultaneous Point-to-Point Operation
Reference Figure B1 Configuration

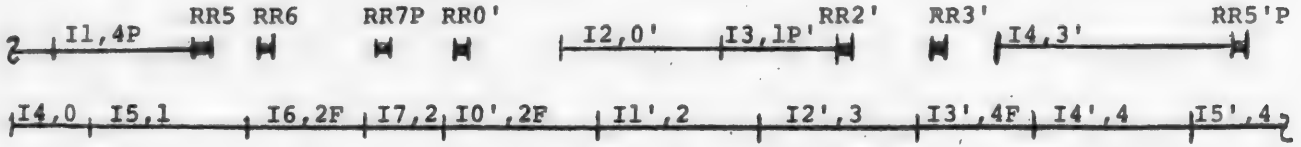
9.1 Continuous Information Frames from Primary and Secondary
(NAB/NAS CLASSES)



9.2 Continuous Primary Information Frames
(NAB/NAS CLASSES)

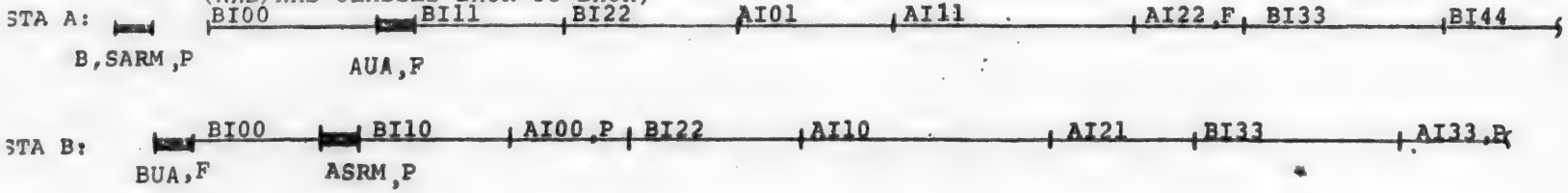


9.3 Continuous Secondary Information Frames
(NAB/NAS CLASSES)

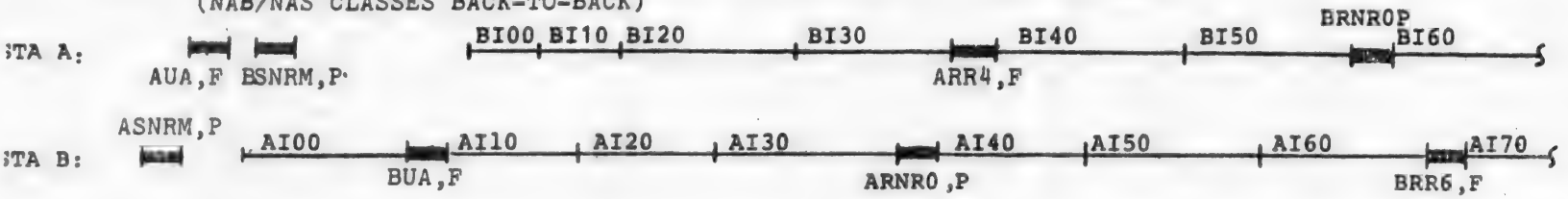


10.0 Double Primary - Secondary ARM TWS Point-to-Point Operation
Reference Figure B2 Configuration

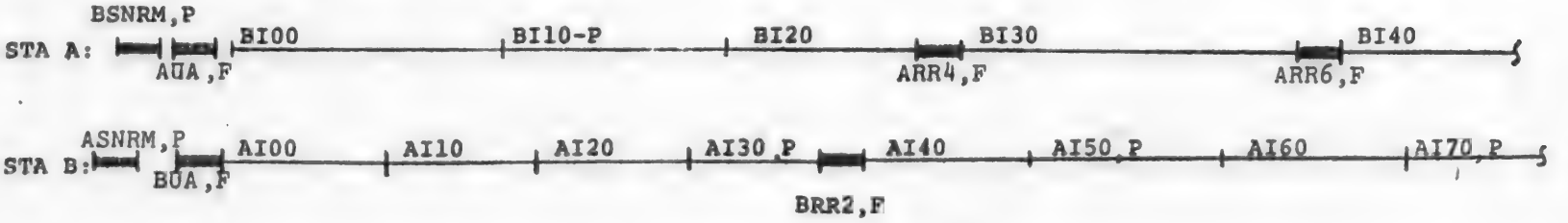
10.1 Primary A/Secondary B in ARM - Primary B/Secondary A in NRM Operation
(NAB/NAS CLASSES BACK-TO-BACK)



10.2 Use of RNR to restrict Information frames from Secondary Operation
(NAB/NAS CLASSES BACK-TO-BACK)



10.3 Secondaries do not transmit Information frames (by prior agreement) Operation
(NAB/NAS CLASSES BACK-TO-BACK)



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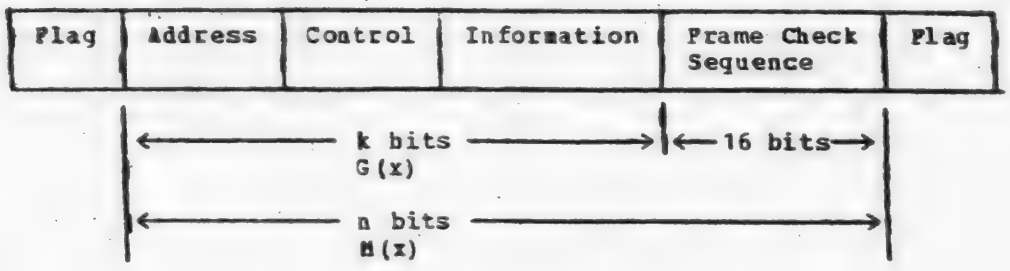
APPENDIX D - FRAME CHECK SEQUENCE (FCS)

D1. Description

The transmission integrity of a received message is determined by use of a Frame Check Sequence (FCS). The FCS is generated by a transmitter, inspected by the receiver and positioned within a frame in accordance with the following diagrams:

Direction of transmission



The procedure for using the FCS assumes the following:

1. The k bits of data which are being checked by the FCS can be represented by a polynomial G(x).

Examples:

a. $G(x) = 10100100 = X^7 + X^5 + X^2 = X^2(X^5+X^3+1)$

b. $G(x) = 00\text{--}010100100 = X^7+X^5+X^2 = X^2(X^5+X^3+1)$

c. $G(x) = 101001 = X^5 + X^3 + 1$

In general, leading zeros don't change G(x) and trailing zeros add a factor of X where n is the number of trailing zeros.

2. The Address, Control and Information field (if it exists in the message) are represented by the polynomial G(x).

3. For the purpose of generating the FCS, the first bit following the opening flag is the coefficient of the highest degree term of G(x) regardless of the actual representation of the Address, Control and Information fields.

4. There exists a generator polynomial P(x) of degree 16, having the form $P(x) = X^{16}+X^{12}+X^{5}+1$

D.2 Generation and use of FCS

The FCS is defined as a one's complement of a remainder, R(x), obtained from the modulo two division of

$$X^{16}\,G(x)+X^{k}(X^{15}+X^{14}+X^{13}+X^{12}+X^{11}+X^{10}+X^{9}+X^{8}+X^{7}+X^{6}+X^{5}+X^{4}+X^{3}+X^{2}+X^{1}+1)$$

by the generator polynomial P(x).

$$\frac{X^{16}\,G(x)+X^{k}(X^{15}+X^{14}+\cdots+X+1)}{P(x)} = Q(x) + \frac{R(x)}{P(x)} \longleftarrow \overline{FCS}$$

The multiplication of G(x) by X^{16} corresponds to shifting the message G(x), 16 places and thus providing the space of 16 bits for the FCS.

The addition of $X^{k}(X^{15}+X^{14}+\cdots+X+1)$ to $X^{16}\,G(x)$ is equivalent to inverting the first 16 bits of G(x). It can also be accomplished in a shift register implementation by presetting the register to all "ones" initially. This term is present to detect erroneous addition or deletion of zero bits at the leading end of M(x) due to erroneous flag shifts.

The complementing of R(x), by the transmitter, at the completion of the division insures that the transmitted sequence M(x) has a property which permits the receiver to detect addition or deletion of trailing zeros which may appear as a result of errors.

At the transmitter the FCS is added to the X^{16} G(x) and results in the total message M(x) of length k+16, where M(x) = X^{16} G(x) + FCS.

The receiver can employ one of several detection processes, two of which are discussed here. In the first process, the incoming M(x) (assuming no errors; i.e. M*(x) = M(x)) is

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multiplied by X^{16}, added to X^{k+16} $(X^{15} + X^{14} - - - - - - + X + 1)$ and divided by P(X).

$$\frac{X^{16}\,[X^{16}\,G(X) + FCS] + X^{k+16}\,(X^{15} + X^{14} - - - + X + 1)}{P(x)} = Qr(x) + Rr(x)/P($$

Since the transmission is error free, the remainder Rr(x) will be "0001110100001111" (X^{15} through X^{0}).

Rr(X) is the remainder of the division: $\frac{X^{16}\,L(x)}{P(x)}$

where $L(x) = X^{15} + X^{14} - - - - - + X + 1$. This can be shown by establishing that all other terms of the numerator of the receiver division are divisible by P(x). This will be done below.

Note that $FCS = \overline{R(x)} = L(x)+R(x)$. (Adding L(x) to a polynomial of its same length is equivalent to a bit by bit inversion of the polynomial.)

The receiver division numerator can be rearranged to:

$$X^{16}[X^{16}\,G(x) + X^{k}\,L(x) + R(x)] + X^{16}\,L(x).$$

It can be seen that the first term is divisible by P(x) by inspecting the transmitter generation equation, thus the $X^{16}L(x)$ term is the only contributor to Rr(x).

The second process differs from the first in that another term ($X^{16}L(x)$) is added to the numerator of the generation equation. This causes a remainder of zero to be generated if M*(x) is received error free.

D.3 Implementation

A shift register FCS implementation is described in detail here. It utilizes "ones presetting" at both the sender and the receiver and the receiver does not invert the FCS. The receiver thus checks for the non-zero residual Rr(x) to indicate an error free transmission.

Figure D.1 is an illustration of the implementation. It shows a configuration of storage elements and gates. The addition of $X^{k}(X^{15}+X^{14}-------+X+1)$ to the X^{16} G(x) can be

accomplished by presetting all storage elements to a binary value "1".

The one's complement of R(x) is obtained by the logical bit by bit inversion of the transmitter's R(x).

Figure D.1 shows the implementation of the FCS generation for transmission. The same hardware can also be used for verification of data integrity upon data reception.

Before transmitting data, the storage elements, $X_0 - X_{15}$ are initialized to "ones". The accumulation of the remainder R(x) is begun by enabling the "A" and thereby enabling gates G2 and G3. The data to be transmitted goes out to the receiver via G2 and at the same time the remainder is being calculated with the use of feedback path via G3. Upon completion of transmitting the k bits of data, the "A" is disabled and the stored R(x) is transmitted via G1 and I1 while G2 and G3 are disabled. The I1 provides the necessary inversion of R(x).

At the receiver, before data reception, the storage elements, $X_0 - X_{15}$ are initialized to "ones". The incoming message is then continuously divided by P(x) via G3 ("A" enabled). If the message contained no errors, the storage elements will contain "0001110100001111" (X^{15} through X^0) at the end of the M*(x).

Figure D.2 is an example of the receiver and transmitter states during a transmission of a 19 bit G(x) and a 16 bit FCS.

The implementation of the FCS generation and the division by P(x) as described in this Appendix is used as an example only. Other implementations are possible and may be utilized. This standard only requires that the FCS be generated in accordance with the rules of Sections 3.5 and 12.1 and that the checking process involve division by the polynomial P(x). Furthermore, the order of transmission of M(x) is the coefficient of the highest degree term first and thereafter in decreasing order of powers of x, regardless of the actual representation of fields internal to M(x).

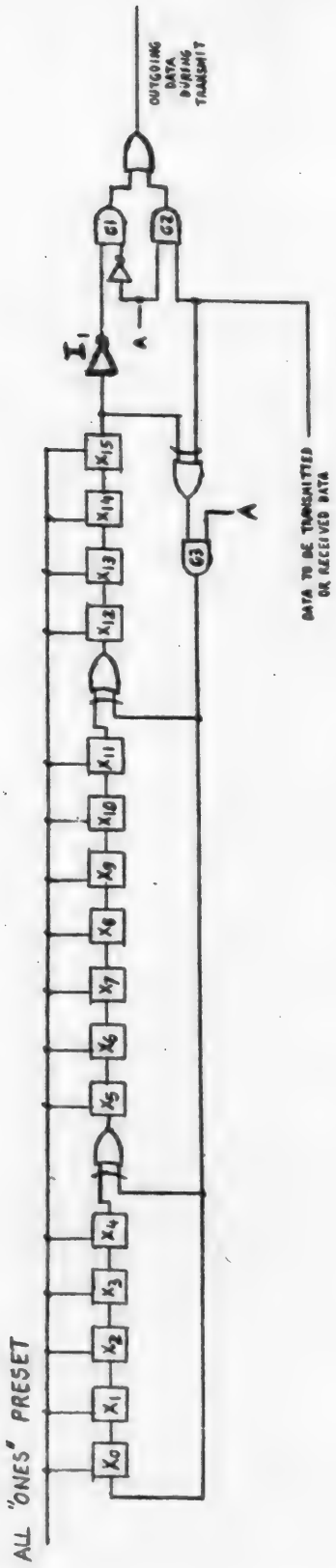

FIGURE D1. FCS IMPLEMENTATION

D5

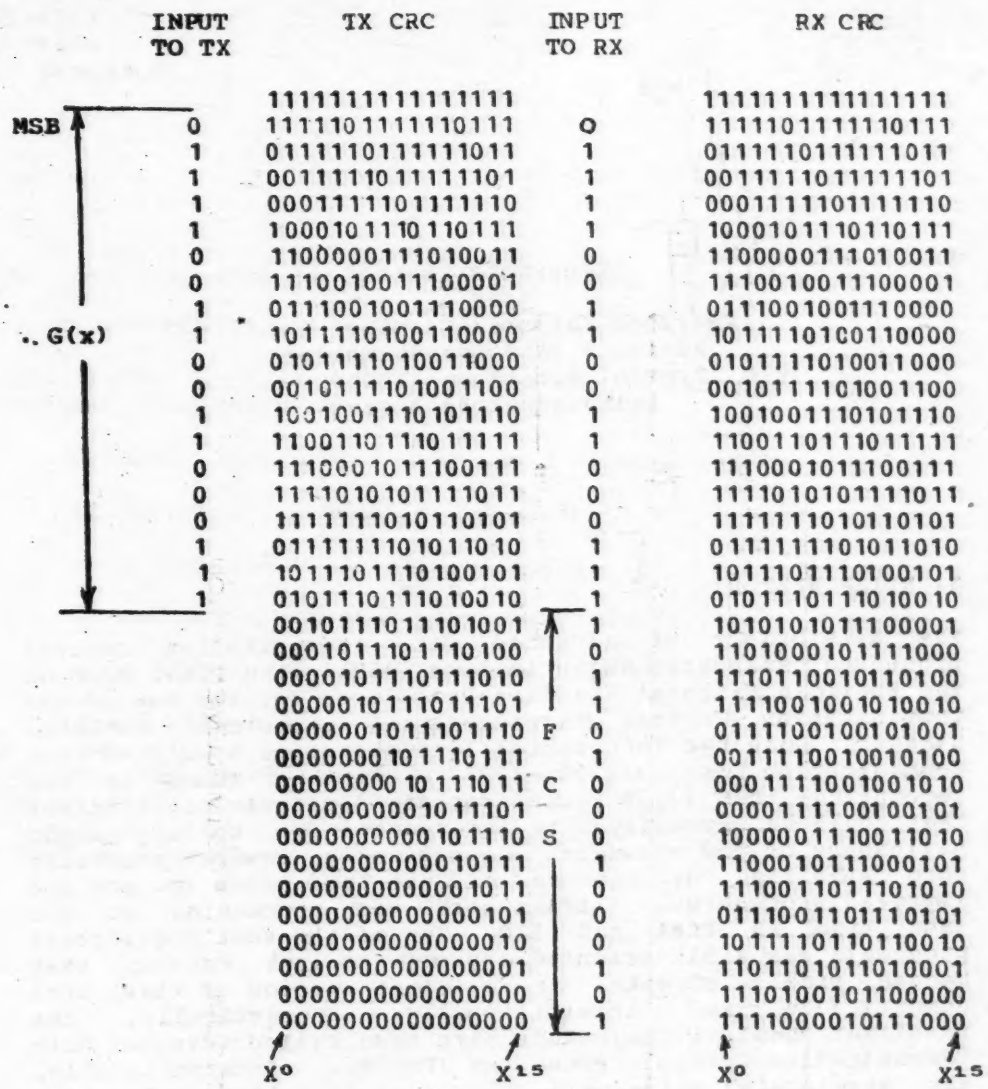

FIGURE D.2 FCS EXAMPLE

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EXPOSITORY REMARKS for American National Standard for Advanced Data Communication Control Procedure (ADCCP) - Independent Numbering

A. BRIEF HISTORY

The development of advanced data communication control procedure standards began in late 1969 during final work on the American National Standard-Procedures for the Use of the Communication Control Characters of American National Standard Code for Information Interchange in Specified Data Communication Links (X3.28 - 1971). At that time, it was recognized that X3.28 lacked certain desirable capabilities that would be impractical to incorporate due to the basic philosophy of the standard. Consequently, several proposals were submitted by members of the Task Group for new and improved procedures. Similar work was proceeding at the same time in ECMA and ISO. One of the most significant proposals was a bit-oriented approach to link control that became widely accepted in a short period of time, both domestically and internationally. Domestically, the resultant control procedure have been called Advanced Data Communication Control Procedures (ADCCP). Internationally, the development going on in this area is called HDLC - High Level Data Link Control.

The original bit-oriented proposal and most of the work, both domestically and internationally, was based on a dependent/single sequence number per frame. In late 1971, a proposal was submitted for independent/dual numbering. It was the general concensus at that time, both domestically and internationally, that the net advantages over the disadvantages of the independent/dual numbering approach was not great enough to warrant working on the two procedures in parallel. Consequently, the American National Standard for ADCCP - Dependent Numbering evolved. Now that the work on dependent/single numbering is complete, the efforts of the

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Task Group are directed toward this proposed American National Standard for ADCCP - Independent Numbering.

B. MAIN TECHNICAL ARGUMENTS AND RELATIONSHIP WITH ISO

The basic objectives of the Advanced Data Communication Control Procedures are to provide:

a) Full transparency and code independence,

b) Efficient interactive operation,

c) A High level of reliability,

d) Two-way alternate and two-way simultaneous operation

e) A high level of modularity

These objectives have been largely met.

During the four-year period of ADCCP development, there has been active liaison with both the ECMA and ISO spheres of interest. As a result each group's activity has influenced that of the other.

FED-STD-1003

PREPARING ACTIVITY:

Office of the Manager
National Communications
System (NCS-TS)
Washington, DC 20305

Records of coordination with affected Federal agencies are maintained by the preparing activity.

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